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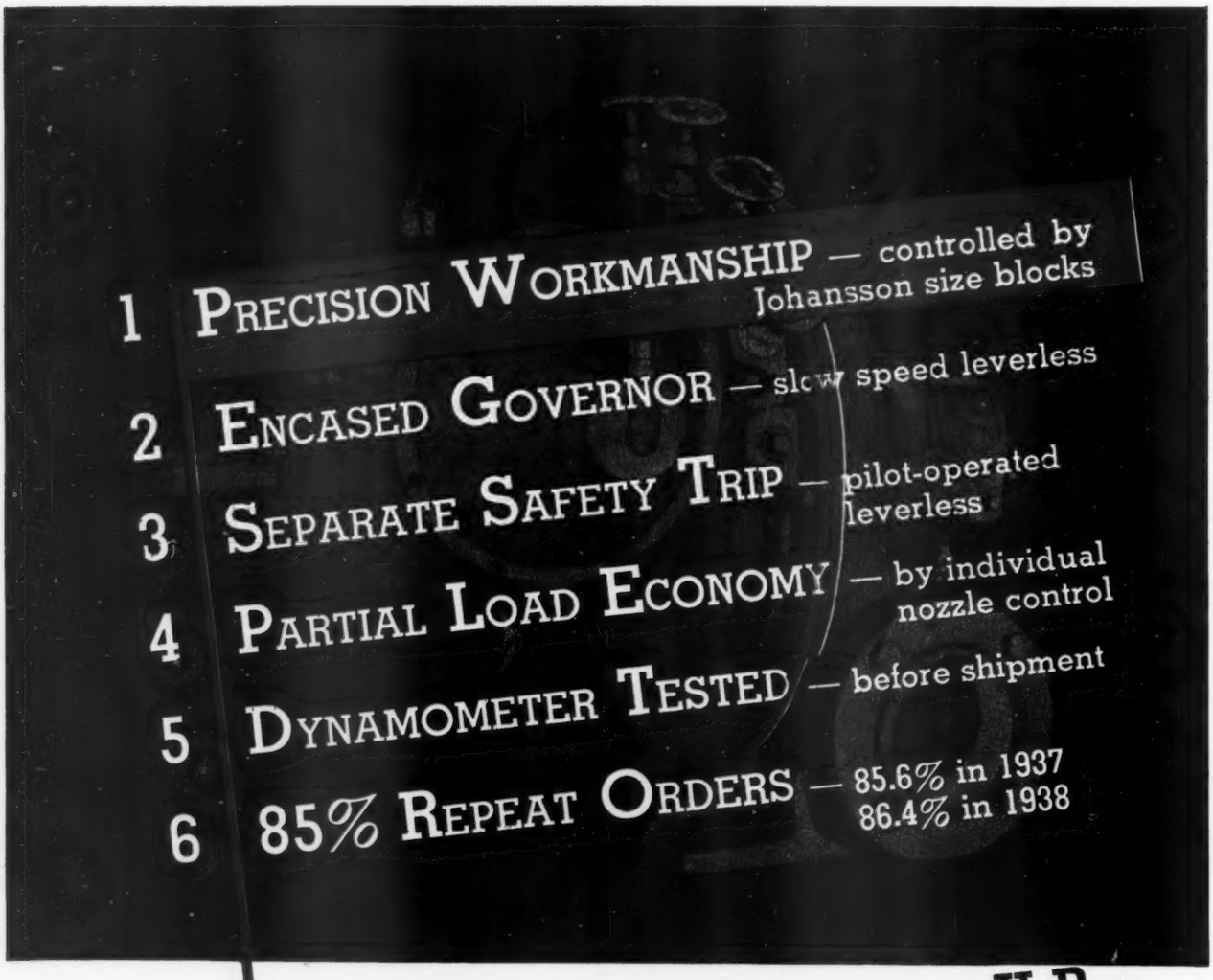
MALPASO DAM, PERU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ON THE COVER

OUR cover picture is a bird's-eye view of the dam in the high Andes that is described in our first article. The structure was built by the Cerro de Pasco Copper Corporation to supply hydro-electric power for its extensive ore-reduction works at Oroya, a short distance away.

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IN THIS ISSUE

FACED with the problem of building, at a conservative cost, a serviceable power dam in a narrow gorge the bottom of which is composed of glacial drift 140 feet thick, the engineers adopted a type of rock-fill structure that they had designed and successfully constructed some years previously in California. To prevent water from flowing underneath the dam, a concrete cut-off wall was extended down to bedrock and notched into the canyon side walls. The heel of the main structure rests on top of this wall into which is keyed a concrete apron that is on the upstream face of the dam and that forms a water seal for it. Precautions taken against the serious cracking of this apron as a result of any movement of the dam have thus far proved to be very effective; and there is now less leakage through the structure than when it was first placed in service. For the information embodied in our description of this dam and the illustrations included with it, we are indebted to Sanderson & Porter, the engineering firm responsible for the design.

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THE *J. W. Van Dyke*, the first of three new Atlantic Refining Company oil tankers, is described in our second article. The power plant of this ship was engineered along lines that have not previously been applied to marine practice in this country. In view of the high efficiencies the vessel has thus far shown, it seems reasonable to predict that the pioneering done by Chief Engineer Goldsmith and his staff will have considerable bearing upon the design of future tankers.

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IN RECENT years we have published several articles dealing with the development of the modern rock drill. Another one is presented this month, and in it will be found not only some additional historical data but also facts that emphasize the important contribution the modern rock drill makes to industrial and social progress.

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A Peruvian Dam of Unusual Design

Allen S. Park

THE POWER HOUSE

Above is an exterior view of the generating station, with the differential surge tank in the background. The interior view (right) shows the three 17,000-kva. generators at present set up. Water for the operation of this plant is conveyed 7,500 feet from Malpaso Canyon Dam by tunnel, and reaches the turbines through penstocks 8½ feet in diameter. Provision has been made for adding a fourth unit when it is needed.

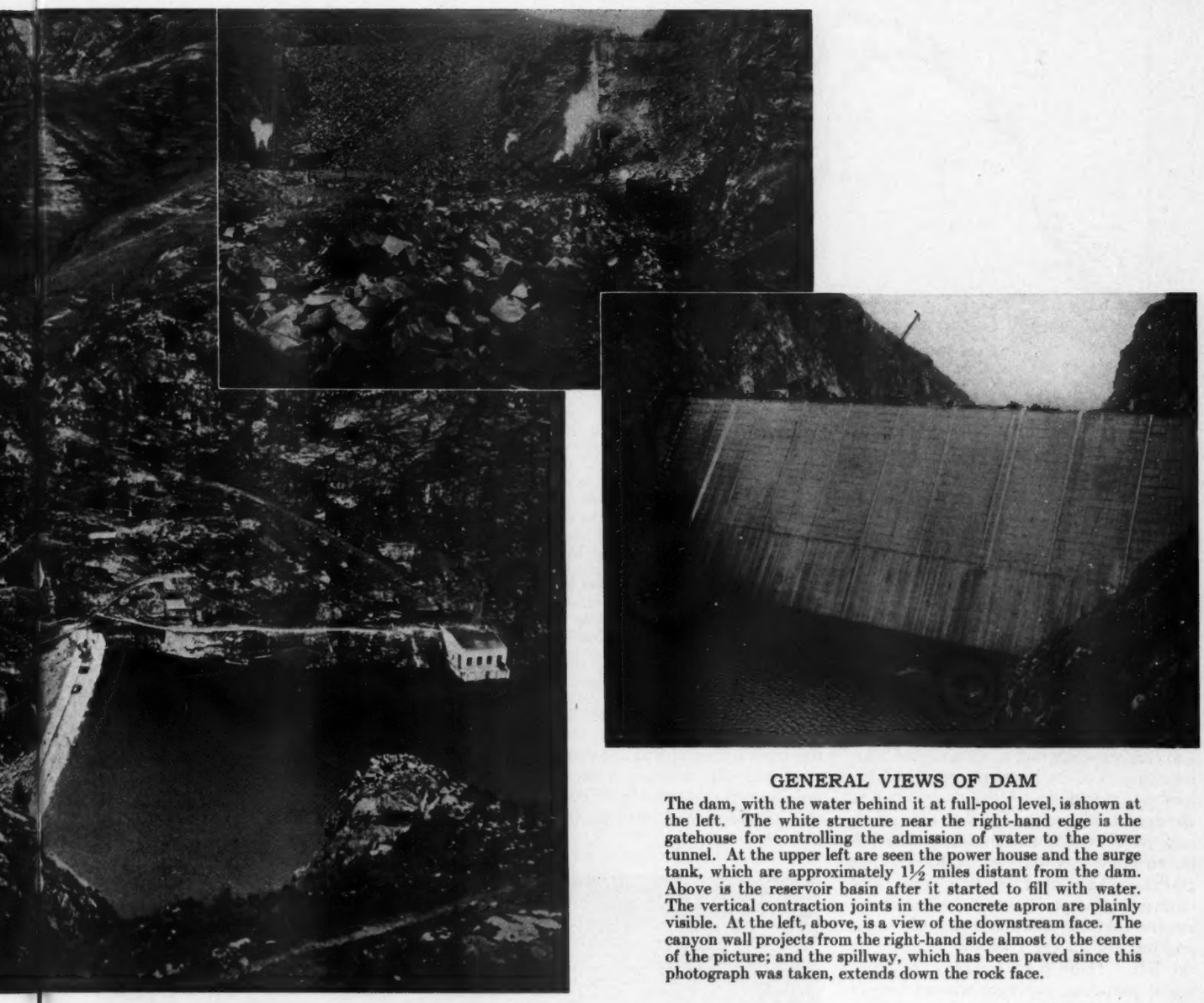
A HIGH, rock-fill dam of unusual design is one of the features of a hydro-electric power project recently completed in Peru by the Cerro de Pasco Copper Corporation. It is located on the Mantaro River, a tributary of the Amazon, and about 15 miles upstream from the Town of Oroya where much of the power will be used. The dam site is a narrow gorge, called Malpaso Canyon, through which the river flowed at El. 12,515 between walls of porphyry rock intruded in the sedimentary formation that predominates at the surface in that general area.

The gorge is at least partially of glacial origin, and is filled to a depth of approximately 150 feet with bowlders, gravel, and sand. At the dam site it is about 175 feet wide at the former level of the river and narrows to a bottom width of approximately 40 feet. It would have been too costly to excavate all the material that would have had to be removed to rest a dam of conventional design on bedrock. Accordingly, there was designed a rock-fill dam the heel of which is supported by a solid-concrete cut-off wall extending from El. 12,470 down to bedrock and the body of which rests on the yielding material of the river bed. The cut-off wall is 105 feet high, and the dam proper rises an additional 255 feet, making an over-all height of 360 feet from bedrock to the dam crest. The length of the dam at the crest is 497 feet.

From the dam, a power tunnel, about 7,500 feet long, delivers water to the power house, the tailrace of which is at El. 12,452. At the lower end of this tunnel are four penstock take-offs of which three are in use while the fourth is held in reserve for future development. Each of the three generating units now in service consists of a vertical-shaft water wheel with a rated capacity of 17,500 hp. when operating at 257 rpm. under a net head of 240 feet, and is direct connected to a 17,000-kva. generator with all accessories for governing the wheels and controlling and measuring the electrical output. Current is developed at 11,000 volts and stepped up to 50,000 volts for transmission.

The Mantaro River's tributaries rise on the eastern slope of the highest ridge of the Andes Mountains in Central Peru. Within its drainage area is Lake Junin, which lies at an altitude of 13,420 feet and has a surface area at normal level of 147 square miles. As a part of the undertaking, there was reared on the Mantaro a low dam—called Upamayo Dam—by means of which water can be diverted into Lake Junin during high-flow periods and then released during dry periods to flow down the river to the Malpaso Canyon Dam. In this manner the upper 10 feet of the lake's water is controlled and its surface elevation made to fluctuate with the season between El. 13,410 and 13,420.

The upstream section of the Malpaso



GENERAL VIEWS OF DAM

The dam, with the water behind it at full-pool level, is shown at the left. The white structure near the right-hand edge is the gatehouse for controlling the admission of water to the power tunnel. At the upper left are seen the power house and the surge tank, which are approximately 1½ miles distant from the dam. Above is the reservoir basin after it started to fill with water. The vertical contraction joints in the concrete apron are plainly visible. At the left, above, is a view of the downstream face. The canyon wall projects from the right-hand side almost to the center of the picture; and the spillway, which has been paved since this photograph was taken, extends down the rock face.

Canyon Dam consists of derrick-laid rocks and tapers from a bottom thickness of 150 feet to a top thickness of 12 feet. The upstream face has a slope of 1 horizontal to 2 vertical, and the downstream face has a slight batter of about 1 in 20. On the upstream face is a rubble-masonry wall which is laid in portland-cement mortar and ranges in thickness from about 6 feet at the bottom to 3 or 4 feet at the top. This facing is made of large, selected rocks some of which extend into the dry wall, thus bonding the two sections together. Against the upstream face of the rubble wall is laid a reinforced-concrete apron which serves as a water seal.

The downstream section of the dam is composed of dumped rock. This has a uniform downstream slope of 1½ horizontal to 1 vertical, with a surcharge of material, or source of supply, at the top that will serve to compensate for the expected settlement. This surcharge is 10 feet wide at the top and varies in height from 5 feet at the axis of the dam to 2 feet at the ends. In addition, waste rock from the excavation for the spillway channel was used to load the toe of the dam and also the natural bed of the river to a point 400 feet downstream from the toe.

In order to increase bearing and contact areas, to lessen settlement, and to add to the weight of the derrick-laid upstream wall, the spaces between large rocks were hand chinked with smaller rocks and quarry spalls, after which river gravel and sand were washed into the remaining interstices by streams of water 1½ inches in diameter and having a nozzle velocity of more than 100 feet a second. In placing large rocks with derricks, care was taken to get a good bearing of bedding surfaces and good end contacts with large rocks already in position before doing any chinking or washing in of gravel. The native workmen employed were very skillful in this type of dry-wall construction. They are descendants of the ancient Incas, whose ability along this line is evidenced by the remains of many fine structures in Peru.

Material for the dam was obtained from a quarry on the left bank of the gorge. The dumped section was started by placing a line of material across the canyon from wall to wall, and was continued by dumping rock down both slopes from the top of this fill. The upstream face formed a *V* with the downstream face of the derrick-laid wall. As the two sections were built simultaneously, it was possible to keep the bottom of this V-shaped pocket 5 to 10 feet below the top of the derrick-laid wall and thus develop considerable upstream thrust against the downstream face of the latter section before the water load was brought to bear against it from the other side.

Only sound quarry rock was placed in the dumped-fill section, and all material from seams was wasted. As in the case of the

GENERAL LAYOUT

This development is located in Central Peru and roughly east of Lima, on the eastern side of the Andes. It supplies some of the electric power for the operation of the Cerro de Pasco Copper Corporation's reduction works at Oroya, approximately 15 miles down the Mantaro River. The power tunnel has a cross-sectional area equivalent to a circle 18.4 feet in diameter, except for 473 feet at its lower end where there is a 17-foot-diameter, riveted steel pipe from which four 8½-foot-diameter penstocks lead to the power house. The Punabamba River crosses the tunnel line in a deep gorge. As the grade was near the surface at that point, an inclined shaft was driven to the tunnel line and headings were then opened in both directions.

derrick-laid section, voids were filled with gravel and quarry fines by streams of water, and care was exercised to obtain good bearing contacts of the larger pieces of rock before this was done. Also, as provided in the specifications, the faces of the quarry rock were washed clean of fine materials before more was dumped on them. The gravel and sand used for filling voids came from a river deposit, about 3 miles downstream, that was also the source of the aggregates for all the concrete required on the job. These fines consisted of hard, sound particles, and were washed free of clay, loam, and silt before being delivered to the dam.

The purpose of the concrete cut-off wall is, of course, to prevent water from flowing through the unconsolidated material on which the dam rests at a velocity great enough to remove or disturb any of it. To accomplish this, the cut-off is notched into sound rock across the bottom of the gorge and up both sides from bottom to top. In addition, the foundation as well as the abutment rock was grouted by means of pipes carried upward through the concrete. These pipes were inserted in previously drilled holes, and grout was not introduced until the cut-off wall had risen high enough to insure adequate penetration under the desired pressure. The holes in the bottom were vertical and averaged 8 feet in depth. Those in the side walls were at an angle of 45° and from 12 to 17 feet deep.

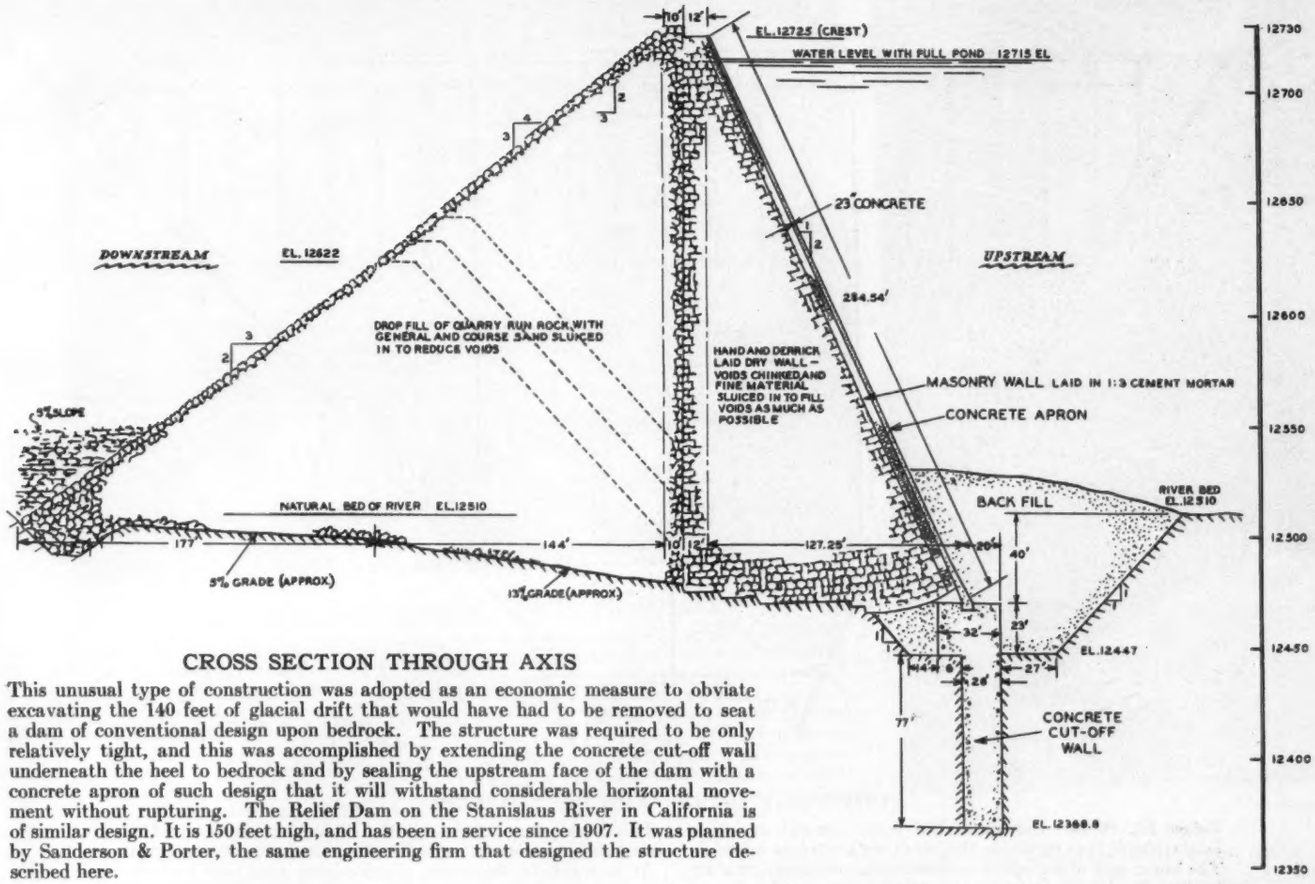
In order to build this wall, it was necessary to excavate a trench 150 feet deep the full width of the gorge through the mixed material of the river bed. The initial 70 feet of the excavating was in open cut, but from that point on down to the bottom of the trench digging was continued between steel-sheet-pile retaining walls. As the material penetrated was highly pervious, suitable provisions had to be made for diverting the river, for keeping the seepage water down to a volume that would permit the excavating and concrete pouring to be done efficiently, and for the disposal of the water that entered the trench.

Construction work was started in 1929; and the industrial outlook at that time was such that it was deemed desirable to push operations with all possible speed to make additional electrical power available for the smelting and refining plants at Oroya. The building of the power house and driving of the power tunnel were undertaken first, the plan being to use the latter as a means of diverting the river during the rearing of the dam. To expedite progress on the dam, however, it was decided to drive a shorter tunnel, for diversion purposes only, around the dam site. This was begun in 1929 and finished in 1930. If the coming of the depression could have been foreseen, this work would not have been done, for all construction activities were suspended in 1931 and not resumed until 1934. But in the meanwhile, the power house, tunnel, and Upamayo Dam had been completed, and some work preliminary to the building of the Malpaso Dam had been done.

For diverting the river, a dam was constructed of timber cribs filled with rock and having a wall of steel sheet piling driven along its upper face to a depth of 15 feet. This structure was located about 50 feet downstream from the portals of the diversion tunnels and about 300 feet upstream from the trench for the cut-off wall. The water surface behind the diversion dam was 165 feet higher than the bottom of the trench. This head, along with the nearness

WASHING FINES INTO VOIDS

A view of the derrick-laid section, showing a high-pressure water jet in use washing clean sand and gravel into spaces between large rocks. These were laid with care to obtain good bearing and end contacts. Any large spaces remaining were chinked before washing in the fine material.

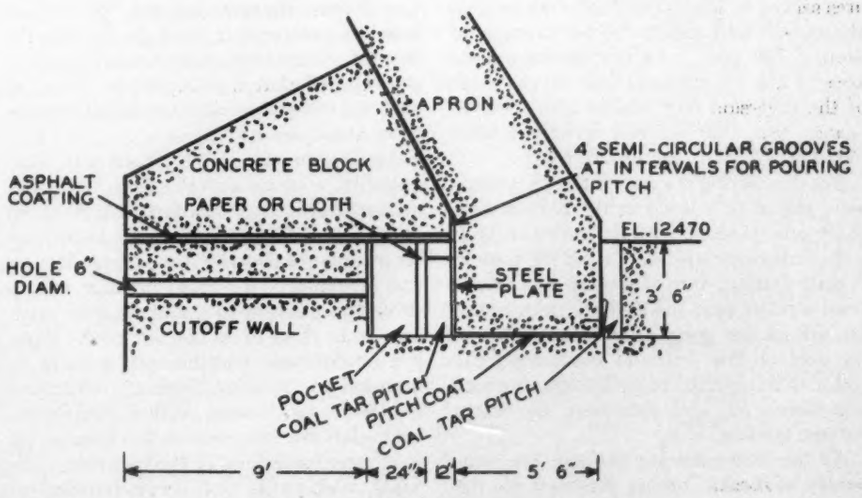


CROSS SECTION THROUGH AXIS

This unusual type of construction was adopted as an economic measure to obviate excavating the 140 feet of glacial drift that would have had to be removed to seat a dam of conventional design upon bedrock. The structure was required to be only relatively tight, and this was accomplished by extending the concrete cut-off wall underneath the heel to bedrock and by sealing the upstream face of the dam with a concrete apron of such design that it will withstand considerable horizontal movement without rupturing. The Relief Dam on the Stanislaus River in California is of similar design. It is 150 feet high, and has been in service since 1907. It was planned by Sanderson & Porter, the same engineering firm that designed the structure described here.

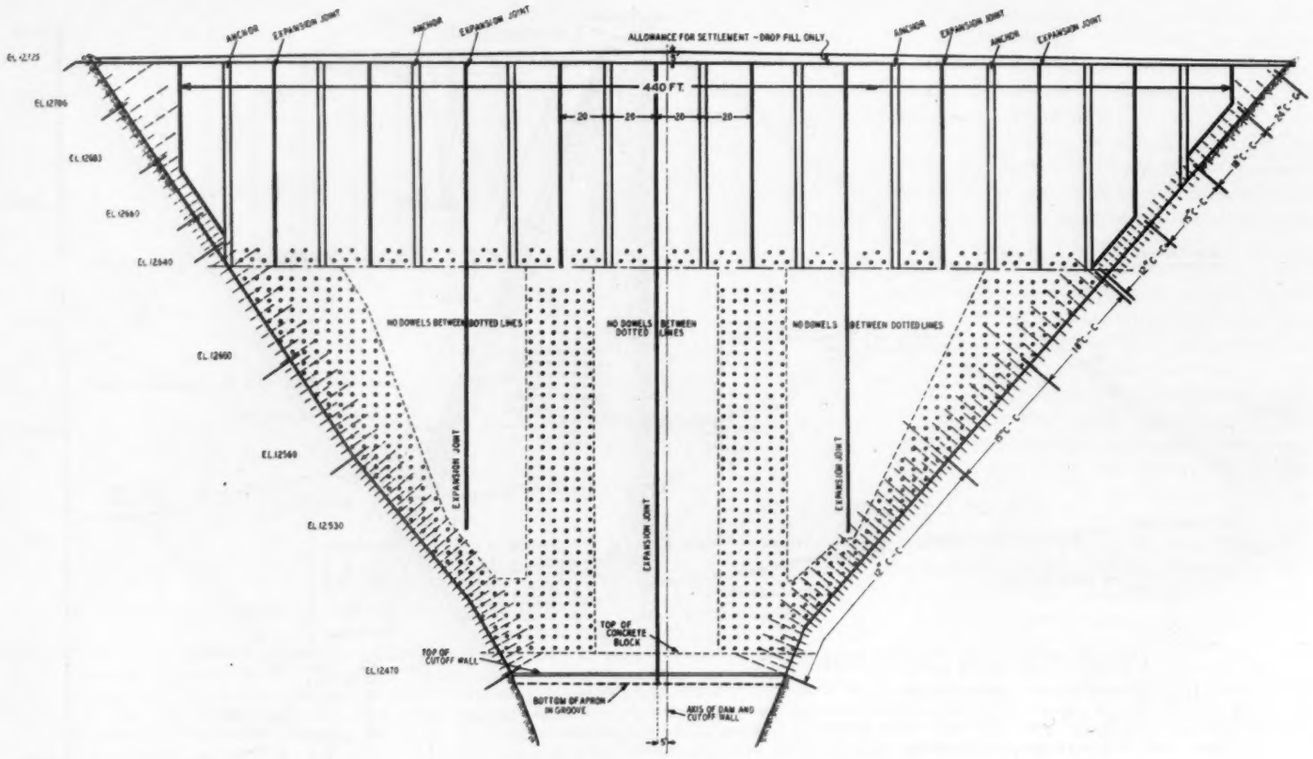
of the dam to the trench and the loose character of the intervening ground, made the problem of keeping excessive quantities of water out of the trench a serious one. To lessen the porosity of the river-bed material, it was decided to inject hot asphalt—which is liquid when placed and solid when cold—into the ground where the diversion dam was to rise. Its introduction was expected to plug the larger openings and to reduce the size of the smaller ones by compressing the material.

The American Asphalt Grouting Company of Chattanooga, Tenn., was employed to do this work, and sent down the necessary equipment and materials and an experienced man to direct the operations. A line of 3-inch pipes, spaced 7 feet apart, was put down to ledge rock across the canyon at the dam site. In each casing there was placed a 1½-inch pipe perforated with ¾-inch holes at 6-inch intervals for 20 feet from the bottom. This pipe was run down to ledge rock, and the casing was then withdrawn partway so that the pipe was unshielded up to the point where the perforations ended. A stopper to fill the annular space between the 1½- and 3-inch pipes was next put in position and forced down to the foot of the casing. Hot liquid asphalt pumped through the 1½-inch pipes issued from the openings and was thus forced through the gorge fill. The pumping pressures ranged from 20 to 600 pounds per square inch. The asphalt was kept hot by passing an electric current through an iron wire that was threaded into the inner pipe to the bottom of which it was connected but from which it was otherwise insulated. When a hole took a comparatively large amount of asphalt under low pressure, it was assumed that the material was going beyond the limits within which grouting was to be confined. Under such conditions the current was switched off and the asphalt allowed to cool, after which the current was turned on again and pumping resumed when the asphalt in the pipe had reached the desired temperature.



DETAILS OF APRON BASE

The base of the concrete apron on the upstream face of the dam rests in a groove in the top of the cut-off wall. To allow the apron to move horizontally in case of settlement of the dam, spaces were left between it and the sides of the groove, both upstream and downstream. Coal-tar pitch was placed in these; and in the concrete on the downstream side are pockets into which the pitch will be forced if enough pressure is applied. Leading from these pockets and through the concrete of the cut-off wall are ducts through which the pitch can be extruded.



CONSTRUCTION OF CONCRETE APRON

Below El. 12,640, the apron has three vertical expansion joints: above that elevation the joints are at 40-foot intervals. The lower part of the apron is anchored to its rubble-masonry backing by dowel pins spaced on 5-foot centers and indicated on the drawing by dots. In the upper section, each 40-foot-wide strip of concrete is anchored by a block of concrete, 4 feet wide and 3 feet deep, along its vertical center line. This is seated in a groove in the rubble-masonry wall. Each strip and its anchor block were placed in one continuous pour. At each side of the apron, 1-inch-square steel bars anchored in the rock of the canyon wall extend alternately 7½ and 15 feet into the concrete. Only every third bar is shown in this drawing. The figures along the right-hand edge refer to their spacing.

Following the asphalt-grouting, the diversion dam was constructed, and in a further effort to reduce seepage, a clay blanket was spread on the river bed above it for a distance of 100 feet or more. These measures served to lessen the flow of water into the cut-off-wall trench to an average of around 700 gpm. As the cross-sectional area of the fill material just downstream of the diversion dam covers about 19,500 square feet, the seepage averaged only about 0.036 gpm. per square foot.

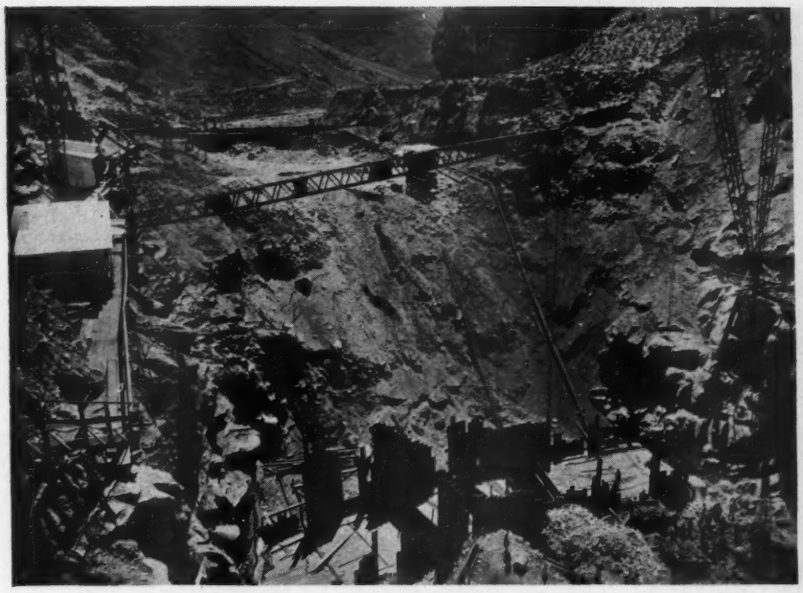
For dewatering the cut-off trench, pumps were placed in a sump at the bottom of a shaft sunk through rock on the right bank a short distance upstream from the trench. A drift draining into this sump was driven from a point near the shaft bottom to the far side of the gorge. As holes drilled in the roof of this drift did not permit the water to drain into it fast enough, the roof was blown off, and thereafter the water entered freely.

As the water flowing through the temporary diversion tunnel returned to the river channel about 1,000 feet downstream from the cut-off trench, seepage from this source had to be taken care of. Until the trench attained depth, this flowed under the sheet piling to the pumps. Later a drift was cut from the upstream side of the trench to connect with the drift leading to the pumps. Before concrete was placed, this water was trapped and carried through the trench in an 8-inch pipe, which was subsequently closed by a valve at each end and filled with grout. Although it had to travel three times as far and had 20 feet less head to force it through the fill, the flow of water from downstream equalled or exceeded that from upstream, showing that the measures taken to curtail seepage from above were effective.

The upper part of the trench was excavated by a steam shovel. With the water drained out of it, the material would stand at a slope of 50 to 60° from the horizontal for a height of 60 to 80 feet. After sheeting was introduced, the usual practice was to drive the piling a foot and then to excavate to or close to its bottom level. Thus, if a bowlder was encountered, it could be removed to facilitate driving. Structural steel wales and bracing, with welded joints, held apart the two rows of sheeting, which were later embedded in the concrete. The 6,000 cubic yards of concrete required to fill the trench was placed in a continuous pour. The cut-off wall was completed 170 days after the river had been diverted.

The upper 24 feet of the cut-off wall is a horizontal true arch, 32 feet thick, with an upstream-face radius of 200 feet: the lower section is in the form of a wide-angle *V*, pointed upstream. It is 26 feet thick at the top and decreases with depth to a thickness of 21 feet at the bottom because of the tendency of the piling to bend inward at the bottom when driven. In the top of this wall there is a groove 3½ feet deep and varying in width from 7 feet at the axis of the dam to 6 feet 4 inches at the edges of the canyon walls. In this slot is set the base of the concrete apron on the upstream face. The apron is 5 feet thick where it notches into the cut-off wall, narrows to 36 inches 18 feet above its base, and then tapers to 23 inches at El. 12,640 and to 10 inches at the top.

In the lower 170 feet of the apron are three vertical contraction joints. One is on the axis of the dam and extends from the top of the cut-off wall at El. 12,470 to El. 12,640. The two others are 80 feet from the respective sides of the center line and extend from El. 12,530 to El. 12,640. These joints were made by leaving a 1-inch space and filling it with soft wood which would undergo crushing when the gaps closed. Each joint is sealed with a soft copper plate the edges of which are embedded in the concrete on both sides of the joint and assume the form of a 3-inch-deep *U* in the joint. Back of the plate is a pocket filled with coal-tar pitch, while the space in front of the plate is calked with oakum soaked



EXCAVATING TRENCH FOR CUT-OFF WALL

So that the concrete cut-off wall on which the heel of the dam rises would rest on rock, it was necessary to sink a trench through the 140 feet of glacial drift that filled the narrow gorge at the dam site. The first 70 feet was removed in open cut, after which two rows of steel sheet piling were driven. Upon reaching rock, a notch or keyway was drilled and blasted. This notch was also carried up the canyon walls. Drilling was done with Ingersoll-Rand S-49 Jackhamers. The bottom of the trench is shown at the right. The lower ends of some of the interlocking steel piles are visible at the upper right, and at the upper left are seen some of the cross members used for bracing. These were later embedded in the concrete.

in pitch and held by a metal plate bolted to the face of the apron.

From El. 12,640 to the top of the dam the apron has vertical contraction joints at intervals of 40 feet. That portion of the face will be exposed for weeks at a time, during periods when the water is drawn down, to daily variations in temperature, which are considerable at this latitude and altitude. The part of the apron below El. 12,640 will be continuously submerged, and the temperature variation will not exceed 10° to 15°F. In addition to taking care of contraction and expansion attributable to temperature changes, both sets of joints will serve another important purpose—that of allowing the apron to adjust itself to any horizontal movement of the dam.

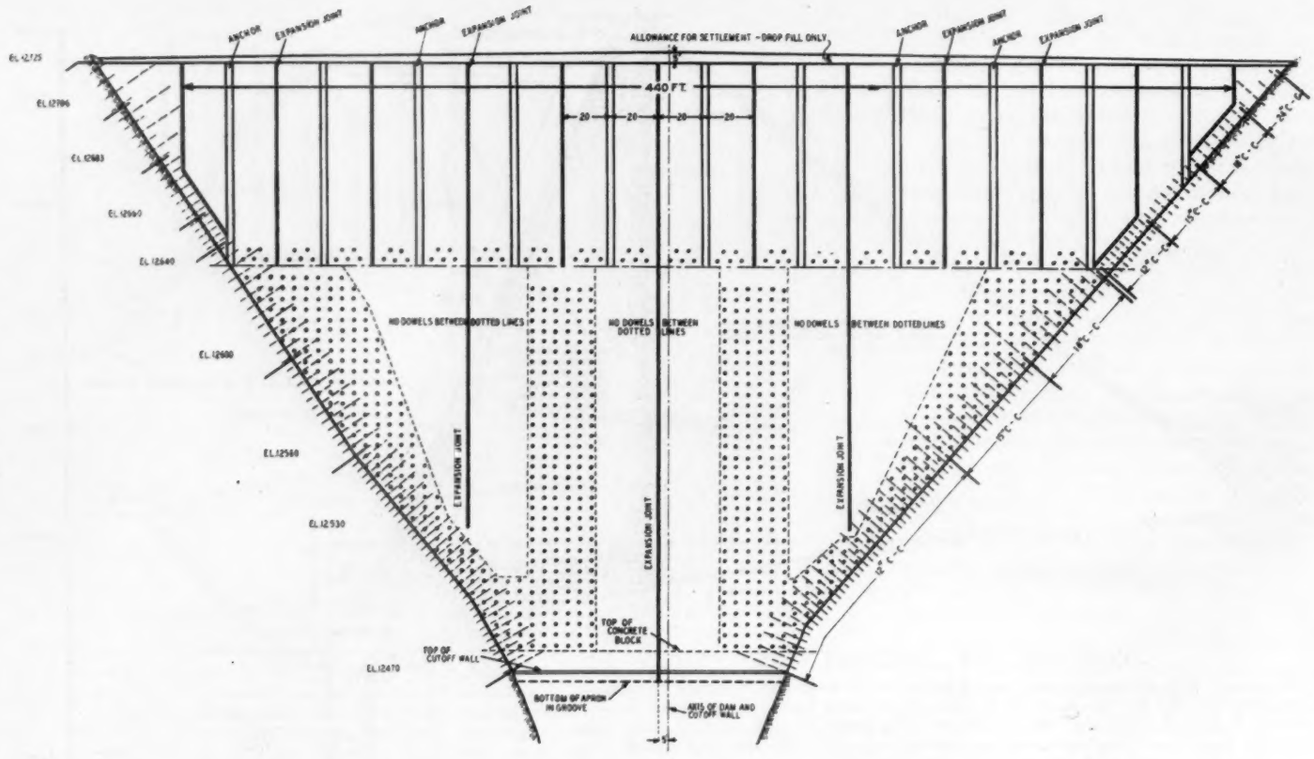
Another feature of the design that is intended to permit the apron to adjust itself to any horizontal movement of the dam with a minimum of damage is the horizontal curvature given to the upstream face. The rubble masonry of the upstream face of the derrick-laid wall and, consequently, the concrete apron which it supports, conform to the outer contour of a cylinder with a 3,000-foot radius the axis of which is in the same vertical plane as the axis of the dam. Measured by the rise at the axis of the dam, the convexity amounts to 0.91 foot at the bottom of the apron where the distance between opposite canyon walls is 140 feet, and to 11.67 feet at the top of the apron where the canyon walls are 500 feet apart.

From the top of the cut-off wall at El. 12,470 to El. 12,660, the apron is reinforced with a double layer of steel bars, each layer containing both horizontal and vertical members. The vertical bars of one layer are 4 inches from the front face at the bottom, the distance decreasing at El. 12,510 and 12,550 to 3½ inches and 3 inches, respectively. In the back layer, the vertical rods are a like distance from the rear face of the apron. Above El. 12,660 there is but one layer running in both directions and placed on the center line of the apron. The accompanying table shows the sizes of the rods and details of their spacing.

The apron is notched into sound rock in the side walls of the gorge to an average distance of 5 feet, the penetration being greatest at the bottom and decreasing gradually towards the top. One-inch square bars, anchored from 3 to 5 feet in the side-wall trenches, project alternately 7½ and 15 feet into the apron just back of the front layer of reinforcing, as given in the table. This special reinforcing is designed to prevent cracking of the apron along and near the side walls where it is held firmly and cannot follow any downstream movement of the body of the dam.

Another construction measure was adopted to help prevent serious cracking of the apron at the sides. Downstream of the side-wall trenches the rock sides of the canyon converge, and into these projecting flanks there was cut a series of shoulders or steps leading toward the axis of the dam. The derrick-laid rock wall rests against these rigid shoulders, and as its thickness increases gradually for a short distance out from the side walls, the amount of its yielding or compression at those points under loading was assumed to be approximately proportionate to the thickness of the wall from apron to shoulder. Thus provision has been made for a gradual increase in the movement of the apron as the distance increases from the side-wall trenches, where there can be no movement. It was believed that this would permit the apron to adjust

Between Elevations	Horizontal Reinforcement Front	Horizontal Reinforcement Back	Vertical Reinforcement Front	Vertical Reinforcement Back
12,470 & 12,510	1″ rd 9.0″ ctrs	1″ rd 18″ ctrs	1″ sq 20″ ctrs	1″ sq 40″ ctrs
12,510 & 12,550	1″ " 10.5″ "	1″ " 21″ "	1″ " 24″ "	1″ " 48″ "
12,550 & 12,595	⅞″ " 10.5″ "	⅞″ " 21″ "	1″ " 28″ "	1″ " 56″ "
12,595 & 12,660	⅞″ " 12.0″ "	⅞″ " 24″ "	1″ " 32″ "	1″ " 64″ "
	On Center		On Center	
12,660 & 12,680	1″ rd 10″ ctrs		1″ sq 20″ ctrs	
12,680 & 12,700	1″ " 12″ "		1″ " 24″ "	
12,700 & 12,725	1″ " 14″ "		1″ " 28″ "	



CONSTRUCTION OF CONCRETE APRON

Below El. 12,640, the apron has three vertical expansion joints: above that elevation the joints are at 40-foot intervals. The lower part of the apron is anchored to its rubble-masonry backing by dowel pins spaced on 5-foot centers and indicated on the drawing by dots. In the upper section, each 40-foot-wide strip of concrete is anchored by a block of concrete, 4 feet wide and 3 feet deep, along its vertical center line. This is seated in a groove in the rubble-masonry wall. Each strip and its anchor block were placed in one continuous pour. At each side of the apron, 1-inch-square steel bars anchored in the rock of the canyon wall extend alternately 7½ and 15 feet into the concrete. Only every third bar is shown in this drawing. The figures along the right-hand edge refer to their spacing.

Following the asphalt-grouting, the diversion dam was constructed, and in a further effort to reduce seepage, a clay blanket was spread on the river bed above it for a distance of 100 feet or more. These measures served to lessen the flow of water into the cut-off-wall trench to an average of around 700 gpm. As the cross-sectional area of the fill material just downstream of the diversion dam covers about 19,500 square feet, the seepage averaged only about 0.036 gpm. per square foot.

For dewatering the cut-off trench, pumps were placed in a sump at the bottom of a shaft sunk through rock on the right bank a short distance upstream from the trench. A drift draining into this sump was driven from a point near the shaft bottom to the far side of the gorge. As holes drilled in the roof of this drift did not permit the water to drain into it fast enough, the roof was blown off, and thereafter the water entered freely.

As the water flowing through the temporary diversion tunnel returned to the river channel about 1,000 feet downstream from the cut-off trench, seepage from this source had to be taken care of. Until the trench attained depth, this flowed under the sheet piling to the pumps. Later a drift was cut from the upstream side of the trench to connect with the drift leading to the pumps. Before concrete was placed, this water was trapped and carried through the trench in an 8-inch pipe, which was subsequently closed by a valve at each end and filled with grout. Although it had to travel three times as far and had 20 feet less head to force it through the fill, the flow of water from downstream equalled or exceeded that from upstream, showing that the measures taken to curtail seepage from above were effective.

The upper part of the trench was excavated by a steam shovel. With the water drained out of it, the material would stand at a slope of 50 to 60° from the horizontal for a height of 60 to 80 feet. After sheeting was introduced, the usual practice was to drive the piling a foot and then to excavate to or close to its bottom level. Thus, if a bowlder was encountered, it could be removed to facilitate driving. Structural steel wales and bracing, with welded joints, held apart the two rows of sheeting, which were later embedded in the concrete. The 6,000 cubic yards of concrete required to fill the trench was placed in a continuous pour. The cut-off wall was completed 170 days after the river had been diverted.

The upper 24 feet of the cut-off wall is a horizontal true arch, 32 feet thick, with an upstream-face radius of 200 feet: the lower section is in the form of a wide-angle *V*, pointed upstream. It is 26 feet thick at the top and decreases with depth to a thickness of 21 feet at the bottom because of the tendency of the piling to bend inward at the bottom when driven. In the top of this wall there is a groove 3½ feet deep and varying in width from 7 feet at the axis of the dam to 6 feet 4 inches at the edges of the canyon walls. In this slot is set the base of the concrete apron on the upstream face. The apron is 5 feet thick where it notches into the cut-off wall, narrows to 36 inches 18 feet above its base, and then tapers to 23 inches at El. 12,640 and to 10 inches at the top.

In the lower 170 feet of the apron are three vertical contraction joints. One is on the axis of the dam and extends from the top of the cut-off wall at El. 12,470 to El. 12,640. The two others are 80 feet from the respective sides of the center line and extend from El. 12,530 to El. 12,640. These joints were made by leaving a 1-inch space and filling it with soft wood which would undergo crushing when the gaps closed. Each joint is sealed with a soft copper plate the edges of which are embedded in the concrete on both sides of the joint and assume the form of a 3-inch-deep *U* in the joint. Back of the plate is a pocket filled with coal-tar pitch, while the space in front of the plate is calked with oakum soaked

EXCAVATING TRENCH FOR CUT-OFF WALL

So that the concrete cut-off wall on which the heel of the dam rises would rest on rock, it was necessary to sink a trench through the 140 feet of glacial drift that filled the narrow gorge at the dam site. The first 70 feet was removed in open cut, after which two rows of steel sheet piling were driven. Upon reaching rock, a notch or keyway was drilled and blasted. This notch was also carried up the canyon walls. Drilling was done with Ingersoll-Rand S-49 Jackhamers. The bottom of the trench is shown at the right. The lower ends of some of the interlocking steel piles are visible at the upper right, and at the upper left are seen some of the cross members used for bracing. These were later embedded in the concrete.

in pitch and held by a metal plate bolted to the face of the apron.

From El. 12,640 to the top of the dam the apron has vertical contraction joints at intervals of 40 feet. That portion of the face will be exposed for weeks at a time, during periods when the water is drawn down, to daily variations in temperature, which are considerable at this latitude and altitude. The part of the apron below El. 12,640 will be continuously submerged, and the temperature variation will not exceed 10° to 15°F. In addition to taking care of contraction and expansion attributable to temperature changes, both sets of joints will serve another important purpose—that of allowing the apron to adjust itself to any horizontal movement of the dam.

Another feature of the design that is intended to permit the apron to adjust itself to any horizontal movement of the dam with a minimum of damage is the horizontal curvature given to the upstream face. The rubble masonry of the upstream face of the derrick-laid wall and, consequently, the concrete apron which it supports, conform to the outer contour of a cylinder with a 3,000-foot radius the axis of which is in the same vertical plane as the axis of the dam. Measured by the rise at the axis of the dam, the convexity amounts to 0.91 foot at the bottom of the apron where the distance between opposite canyon walls is 140 feet, and to 11.67 feet at the top of the apron where the canyon walls are 500 feet apart.

From the top of the cut-off wall at El. 12,470 to El. 12,660, the apron is reinforced with a double layer of steel bars, each layer containing both horizontal and vertical members. The vertical bars of one layer are 4 inches from the front face at the bottom, the distance decreasing at El. 12,510 and 12,550 to 3½ inches and 3 inches, respectively. In the back layer, the vertical rods are a like distance from the rear face of the apron. Above El. 12,660 there is but one layer running in both directions and placed on the center line of the apron. The accompanying table shows the sizes of the rods and details of their spacing.

The apron is notched into sound rock in the side walls of the gorge to an average distance of 5 feet, the penetration being greatest at the bottom and decreasing gradually towards the top. One-inch square bars, anchored from 3 to 5 feet in the side-wall trenches, project alternately 7½ and 15 feet into the apron just back of the front layer of reinforcing, as given in the table. This special reinforcing is designed to prevent cracking of the apron along and near the side walls where it is held firmly and cannot follow any downstream movement of the body of the dam.

Another construction measure was adopted to help prevent serious cracking of the apron at the sides. Downstream of the side-wall trenches the rock sides of the canyon converge, and into these projecting flanks there was cut a series of shoulders or steps leading toward the axis of the dam. The derrick-laid rock wall rests against these rigid shoulders, and as its thickness increases gradually for a short distance out from the side walls, the amount of its yielding or compression at those points under loading was assumed to be approximately proportionate to the thickness of the wall from apron to shoulder. Thus provision has been made for a gradual increase in the movement of the apron as the distance increases from the side-wall trenches, where there can be no movement. It was believed that this would permit the apron to adjust

Between Elevations	Horizontal Reinforcement		Vertical Reinforcement	
	Front	Back	Front	Back
12,470 & 12,510	1″ rd 9.0″ ctrs	1″ rd 18″ ctrs	1″ sq 20″ ctrs	1″ sq 40″ ctrs
12,510 & 12,550	1″ " 10.5″ "	1″ " 21″ "	1″ " 24″ "	1″ " 48″ "
12,550 & 12,595	⅞″ " 10.5″ "	⅞″ " 21″ "	1″ " 28″ "	1″ " 56″ "
12,595 & 12,660	⅞″ " 12.0″ "	⅞″ " 24″ "	1″ " 32″ "	1″ " 64″ "
	On Center		On Center	
12,660 & 12,680	1″ rd 10″ ctrs		1″ sq 20″ ctrs	
12,680 & 12,700	1″ " 12″ "		1″ " 24″ "	
12,700 & 12,725	1″ " 14″ "		1″ " 28″ "	

itself, without serious cracking, to the downstream movement of the dam resulting from settlement and compacting under the water load.

The foot of the apron was sealed into the groove in the top of the cut-off wall in a manner that would allow it to move a short distance downstream with the dam. The top of the cut-off wall was expected to remain rigid or to move only slightly, so provision had to be made for the independent movement of the base of the apron. This was done by giving it a thickness less than the width of the groove. At the axis of the dam there is 24 inches of surplus space, of which 18 inches is on the downstream side of the apron and 6 inches on the upstream side. The groove gradually narrows towards the ends of the dam, and at the side walls the surplus space totals 10 inches, of which 4 inches is on the downstream side of the apron and 6 inches on the upstream side. The uniform space of 6 inches on the upstream side was filled with coal-tar pitch immediately after the apron was poured. The downstream space, varying from 4 to 18 inches in width, was filled with pitch for three-quarters of its height before the foot of the apron was poured. Pockets were left in the concrete cut-off wall downstream of the groove into which the pitch would be forced under the application of sufficient pressure. In addition, ducts of 6-inch diameter leading from each pitch pocket to the downstream face of the cut-off wall were placed in the concrete so that, in case of a relatively large downstream movement of the apron, the pitch would be extruded. A copper plate was sealed into the concrete at the bottom of the groove and into the upstream face of the apron about 9 inches above its base. The plate passes over a 2-inch wood roller that was originally about 6 inches above the line where the plate enters the concrete of the apron.

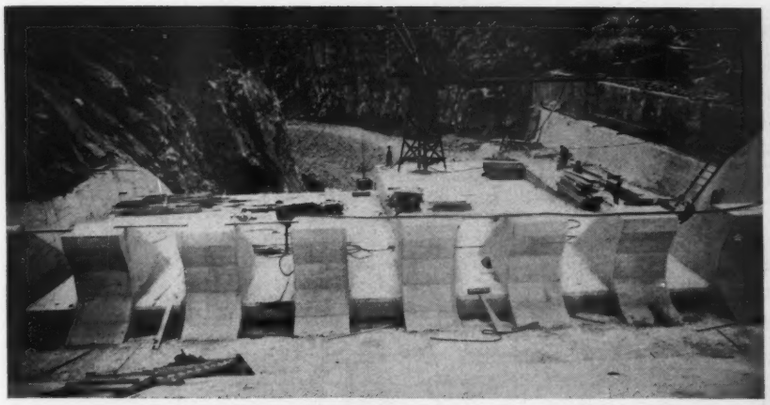
Provisions were made to measure the movement of the heel of the dam at three points in the bottom of the apron just above the cut-off wall. Point No. 1 is 3 feet to the right of the axis, Point No. 2 is 42 feet farther to the right, and Point No. 3 is 37 feet to the left of the axis. Between October 3, 1936, when pouring of the apron was completed, and January 29, 1937, when the reservoir was full to the free spillway crest for the first time, the downstream movement at Point No. 1 was 6 inches; 7⅛ inches at Point No. 2; and 7¼ inches at Point No. 3. These measurements may be inaccurate by as much as ½ inch because of changes, attributable to temperature variations, in the length of the cable by which they were transmitted from the foot of the apron to an observation station above the water line of the full reservoir. Up to the autumn of 1938, the total observed movement at the three points was: 7 inches at No. 1; 9⅜ inches at No. 2; 10¼ inches at No. 3.

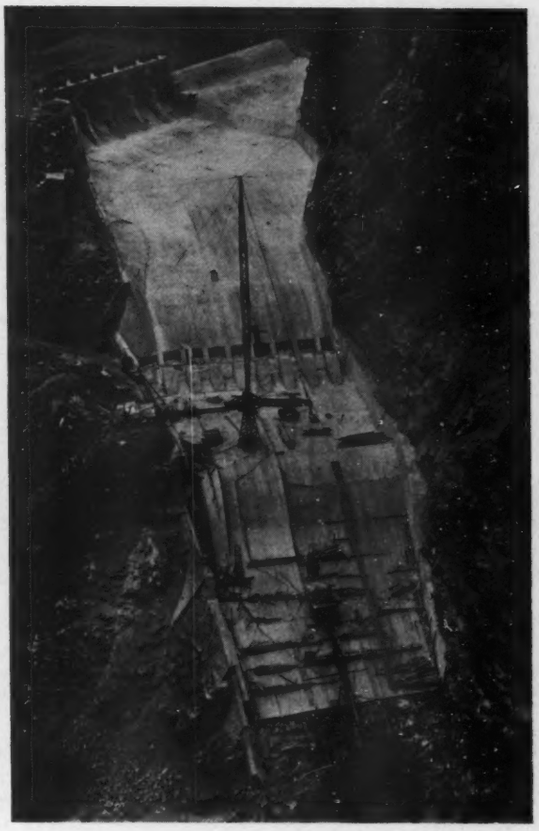
BASE OF RUBBLE WALL

This wall was laid in portland-cement mortar and backs up the derrick-laid dry wall that forms the nucleus of the upstream section of the dam. The rubble wall shown here was faced with a concrete apron which extends down into the groove visible in the top of the cut-off wall. By comparing the height of individual pieces of rock in the wall with that of the human figures, it will be observed that some very large stones were placed in the structure.

The continued tightness of such a dam depends largely upon the amount of its settlement and upon the extent to which the concrete apron can adjust itself to the movement without opening up leakage cracks. It was therefore important that means be provided for measuring the settlement. The internal settlement and compacting of the material on which the dam rests are combined in the total settlement. Both were measured at intervals after placing of the rock began. In order to measure the compacting of the foundation material, a 2-inch pipe was cemented into a large rock in the bottom course of the derrick-laid wall. As the wall rose in height, the pipe was extended to the top of the dam. By taking the elevation of the top of this pipe at regular intervals it was possible to determine how much the foundation was being compacted. The data thus obtained are plotted in an accompanying illustration. The rock in which the pipe is cemented is about on the axis of the dam, 114 feet from the heel. Directly above it, the wall rises to its greatest height, so that the rock load on the base can be assumed to be the maximum. During the construction of the derrick-laid wall, observations were made to determine the combined foundation compacting and the internal settlement of the wall. The results were not satisfactory nor conclusive; but the readings indicated that the internal settlement was small.

Observations were also made during the course of construction of points on the face of the rubble-masonry wall to determine the horizontal movement of the derrick-laid portion of the dam. These points were on the axis of the dam at El. 12,532.5, 12,571, 12,614, 12,655, 12,684, and 12,725 —the top—and were designated as points *A*, *B*, *C*, *D*, *E*, and *F*, respectively. During the ten months starting with May, 1935, Point *A* moved downstream 0.12 foot. By October 1, 1936, when it was submerged, it had returned upstream 0.09 foot, thus leaving it 0.03 foot downstream from its original position. Between October 14, 1935, and February 6, 1936, Point *B* moved downstream 0.32 foot and then returned 0.17 foot by October 1, 1936, when it was submerged permanently. Between February 6, 1936, and June 8, 1936, Point *C* moved downstream 0.3 foot, returned 0.1 foot in the next 32 days and again moved slowly downstream, its net movement to October 6, 1936, being 0.3 foot downstream. Point *D* moved steadily downstream a total distance of 1.2 feet between April 15, 1936, and November 30, 1936. Point *E* likewise had no backward movement and traveled 1.62 feet downstream between May, 1936, and November 30, 1936. Point *F* had a similar unbroken movement of 1.61 feet downstream between July 6, 1936, and November 30, 1936. During construction, the rubble-masonry face of the derrick-laid wall was always brought out to the line it would have followed had there been no horizontal movement between successive lifts. As a consequence, the upstream face





SPILLWAY

The spillway drops 200 feet in a distance of 800 feet; and because of the erosive action of the water, it was necessary to pave the rock face of the canyon wall. At the right is a general view made during the construction period. To arrest the speed of the water, an "energy killer" was placed at about the half-way point. This is shown in detail at the upper left. Each concrete pier is 6 feet wide and 9 feet high, and its upstream face is designed to reverse the direction of the water striking it. A view from overhead (lower left), showing the effect of 14,000 second-feet of water entering the basin. Near the bottom of the spillway is a second energy destroyer, based on the principle of the hydraulic jump.

of the rubble masonry and also of the concrete apron was slightly dished, its profile in a vertical plane parallel to the axis of the dam being slightly concave upstream.

Upon completion of the concrete apron to the top of the derrick-laid wall, at El. 12,725, brass bolts were set in its top and spaced 9 inches on each side of the contraction joints, which are 40 feet apart. Their elevations and the distance of each one from a reference line normal to the axis of the dam were determined and recorded. At frequent intervals since then, observations have been made to ascertain both the horizontal and vertical movements of these markers, and they will be continued until the movement of the dam has ceased. Between October 3, 1936, and February 26, 1939, the horizontal movement of the bolt on the axis was 1.82 feet and its vertical movement was 0.89 foot. About half of this movement took place during the four months from October, 1936, to January, 1937, inclusive, during which the pond was filled for the first time. The movement has been proportionately less towards the side walls. The vertical movement has been about half the horizontal movement, as it should be, so long as the integrity of the apron and the upstream slope of the dam, 2 vertical to 1 horizontal, is preserved.

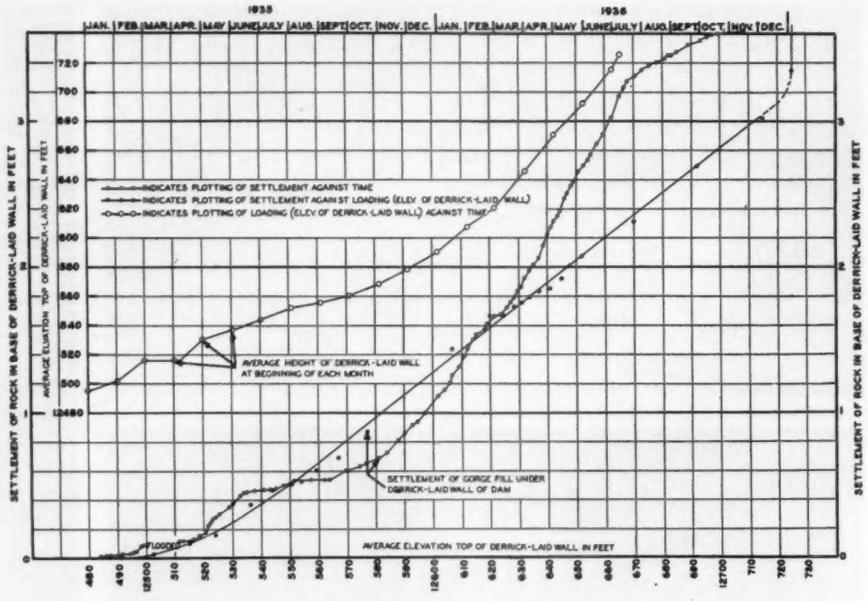
The steps that were taken to make the dam reasonably watertight have proved to be quite effective. It is believed that not more than 3½ second-feet of water is now passing the dam site and that half of this, or perhaps even more, is passing through the canyon side walls beyond the zone reached by grouting. The figure of 3½ second-feet is arrived at by adding to the surface or visible flow, measured by a weir in the river channel 1,000 feet below the dam, an estimate of the subsurface flow. Three pipes, approximately in an upstream and downstream line, were driven into the old bed of the river below the dam to make it possible to obtain readings of groundwater elevations at regular intervals. The first and third pipes are 210 feet apart, and the second is 19.5 feet from the first one.

In any period in which there has been no recent rain or no passage of water over the spillway, a rise of the water table accompanied by an increase in its slope would indicate that the volume of leakage through the dam has increased. Conversely, a lowering of the water table and decrease in its slope would indicate a diminution in leakage. From October, 1936, to October, 1938, the normal difference in the elevation of the water in Pipes Nos. 1 and 3 with full reservoir was 1 foot, thus indicating a slope of the water table of 1 in 210 feet, or 0.00476. Water in Pipe No. 2 stood uniformly about 0.1 foot below that in Pipe No. 1. These observations furnish ground for the inference that there has been a fixed amount of dam leakage with a full pond. Since last October there has been a reduction in the slope of the water table, which would seem to indicate that the leakage has decreased since that time.

The spillway for the dam was formed by cutting a channel into the rock of the canyon wall at the end of the dam on the left bank. The spillway weir is in two sections. Adjacent to the dam, with their crests at El. 12,705, are five Taintor gates, each 20 feet wide. In line with these, and extending toward the canyon wall, is a free spillway 134 feet long, with its weir crest at El. 12,715. With the reservoir surface at El. 12,723.33, the discharge capacity of the spillway weir is more than 36,000 second-feet, but it is expected that not more than one-third of this volume of water will have to be passed over the dam, save at infrequent intervals.

The period of greatest run-off of the Man-

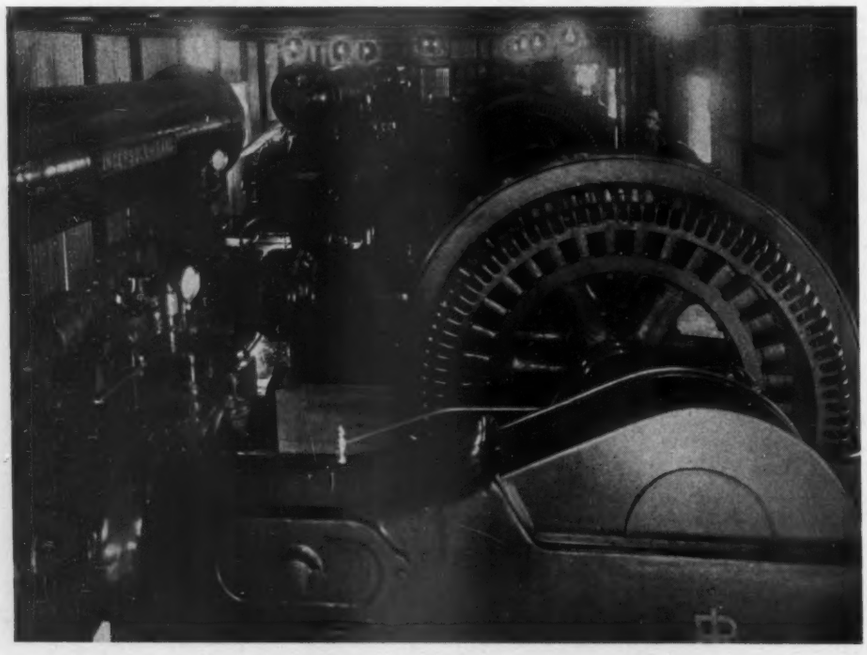
taro River watershed is from January to March, which is the time of greatest rainfall and also the summer season when snow melts in the higher reaches of the Andes. Severe rains may also fall in November and December, and in some years they continue into April and May. During the months of greatest river flow, the gates of Upamayo Dam will be closed to divert water into Lake Junin for storage, and this diversion will, it is estimated, reduce the volume of flow at Malpaso Dam by 40 per cent. By drawing down the water behind Malpaso Dam 15 to 20 feet prior to the rainy season, additional storage capacity will be provided there. These measures, together with the discharge of water for power generation, are calculated to reduce the spillway flood discharge to about one-half the uncontrolled flood flow of the river at Malpaso Canyon. By the exercise of vigilance, and by the use of good judgment in controlling the reservoir level by spillway gates and power-station operation, it is believed that the spillway discharge can be kept down to between 6,000 and 10,000 second-feet in most years and that a discharge of 12,000 second-feet will be rare.


1935
1936
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.
SETTLEMENT OF ROCK IN BASE OF DERRICK-LAID WALL IN FEET
AVERAGE ELEVATION TOP OF DERRICK-LAID WALL IN FEET
INDICATES PLOTTING OF SETTLEMENT AGAINST TIME
INDICATES PLOTTING OF SETTLEMENT AGAINST LOADING (ELEV. OF DERRICK-LAID WALL)
INDICATES PLOTTING OF LOADING (ELEV. OF DERRICK-LAID WALL) AGAINST TIME
AVERAGE HEIGHT OF DERRICK-LAID WALL AT BEGINNING OF EACH MONTH
SETTLEMENT OF GORGE FILL UNDER DERRICK-LAID WALL OF DAM
FLOODS
AVERAGE ELEVATION TOP OF DERRICK-LAID WALL IN FEET

EXTENT OF FOUNDATION SETTLEMENT

Graph of data obtained by taking, at regular intervals during construction, the elevation of the top of a pipe cemented into a large rock in the bottom course of the derrick-laid wall and carried upward as the wall rose in height.

Water flowing over the spillway drops nearly 200 feet in 800 feet. The rock of the mountainside over which it descends was so badly cracked and broken that it was evident that it would be rapidly eroded by the water. Accordingly, it was necessary to pave it with concrete. The floor pavement of this channel has an average thickness of 24 to 30 inches. It is reinforced in both directions and securely anchored to the rock by 1⅛-inch square bolts, one to 80 square feet of concrete. Vent holes prevent uplifting of the pavement by water passing underneath it. The sides of the channel are also faced with reinforced concrete to a height of 10 or 12 feet, and on the mountainsides these walls are doweled to the rock and amply vented.

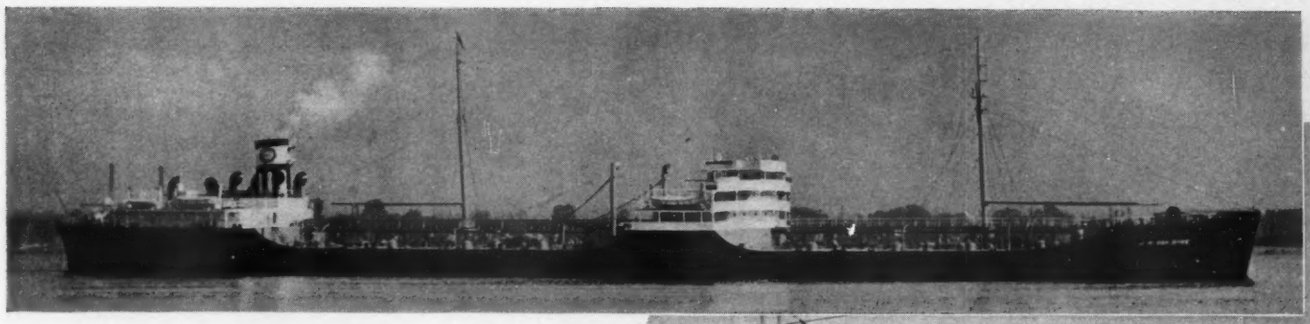


AIR COMPRESSORS

Compressed air was supplied by these three Ingersoll-Rand Class PRE-2 machines, each of which delivered 1,738 cfm. They were driven by direct-connected synchronous motors. Most of the air was used to operate rock drills in driving the power and diversion tunnels, in excavating at the dam site, and in quarrying the rock incorporated in the dam. The tunnels were driven by the heading-and-bench method and with Ingersoll-Rand drifter drills. In the quarry, large quantities of rock were brought down with each blast by the "coyote" method—by drilling tunnels and crosscuts into the rock face and placing large charges of explosives in them. This drilling, as well as that in the canyon bottom and side walls, was done with S-49 Jackhamers.

To reduce the high velocity the water would attain at the lower end of the channel by reason of the steepness of the slope, an "energy killer" was placed in the channel about half way down. This takes the form of a shallow basin about 30 feet long and 100 feet wide. At its downstream edge is a concrete shoulder 30 inches high, and rising from this are eight concrete piers each 6 feet wide and 9 feet high. These are spaced 12 feet apart, center to center, leaving 6-foot openings between adjacent ones. The upstream faces of the piers are shaped so that the water striking them returns upstream. Water enters this basin in an unbroken stream with a velocity of 50 to 60 feet a second, and leaves it very much broken up and frothy with a velocity of 20 to 30 feet a second. A short distance from the final drop, about 200 feet from where the spillway joins the old channel of the river, there is a second energy destroyer. Its design is based on the principle of the hydraulic jump.

The Malpaso Canyon Dam and appurtenant works were constructed by the Cerro de Pasco Copper Corporation under the direction of Harold Kingsmill, general manager of its operations in Peru. J. F. Foran was superintendent of construction. The engineering was done by Sanderson & Porter of New York, N. Y., and H. H. Haggard of that firm was on the job throughout the construction period.



The "J. W. Van Dyke" an Oil Tanker of Distinction

C. H. Vivian

S. S. "J. W. VAN DYKE"

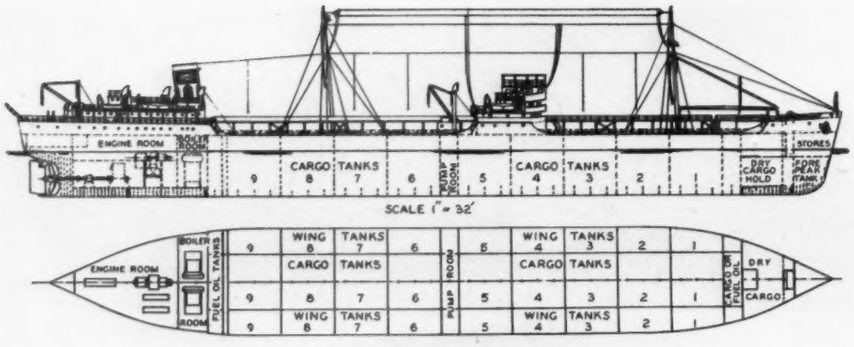
First of a new line of Atlantic Refining Company tankers that embody many special engineering features, including a power plant that more closely approaches land practice than any previously installed in ships. The vessel has a rated sea speed of 13¼ knots, but has been exceeding that figure in service. The bottom view shows a part of the foredeck and the fore-and-aft gangway. This vessel and its sister ship, the "Robert H. Colley," bring the total of electric-driven craft operated by the company to sixteen, a greater number than that owned by any other organization in the world.

WHEN the flying boat *Cavalier* was forced down in the Atlantic Ocean off the United States coast last February, an oil tanker sped to its aid and effected a thrilling rescue of the survivors. The fact that the nearest vessel to the distressed aircraft was an oil carrier is not surprising, for tankers have in recent years become so numerous as to occupy a prominent position in the world's merchant marine. There are approximately 2,000 of them in service, and they sail the Seven Seas, transporting crude oil to refineries and distributing gasoline and other products to markets. The fleet aggregates more than 10,000,000 tons, and was built at a cost of more than $100 a ton. Some 500 of these tankships fly the American flag, as compared with 50 in 1914. In their work of placing fuel and lubricating oils at the disposal of motorists the world over, they operate so efficiently and so economically as to reduce the cost of transportation to a minimum. Despite the fact that they carry flammable cargoes, they are among the safest of the ships afloat. In 1937 their fire loss was only $20,000 on a total insurable value of $100,000,000.

The tanker of a few years ago had little standing. It was a slow, lumbering craft, ill-smelling and generally dirty. But the tankship of today is in a different category. Its speed compares well with that of any freighter, it is trim, spick and span. Single vessels cost as much as $2,500,000, are equipped with the most modern aids to seamanship, and have comfortable fireproof quarters for officers and crews, with air-conditioned lounges and smoking rooms.

During the past twelve months The Atlantic Refining Company has placed in service two distinctive sea-going tankers for carrying petroleum from Gulf Coast points in Texas to its refinery at Philadelphia, Pa. These ships are the *J. W. Van Dyke* and the *Robert H. Colley*. As they are alike in every respect, this description will be confined to the former, which was the first one built. It was constructed by the Sun Shipbuilding & Dry Dock Company at Chester, Pa., and was launched on November 20, 1937, and completed on February 27, 1938. A third tanker of identical design is now underway.

The *J. W. Van Dyke* is noteworthy in several respects. In addition to being the first American-built tanker with turbine-



GENERAL ARRANGEMENT AND PROFILE

electric drive, it utilizes the highest steam pressures and temperatures of any vessel so far constructed in the United States. It also is the first ship to employ alternating current of standard voltage and frequency, as recognized for land practice in this country. The cargo space amidships is of all-welded construction, only the ends being riveted; and it is the largest vessel ever fabricated in this manner. The tanker excels in its cargo-discharging capacity, the time required being approximately one-half of the average needed for other ships of equal size.

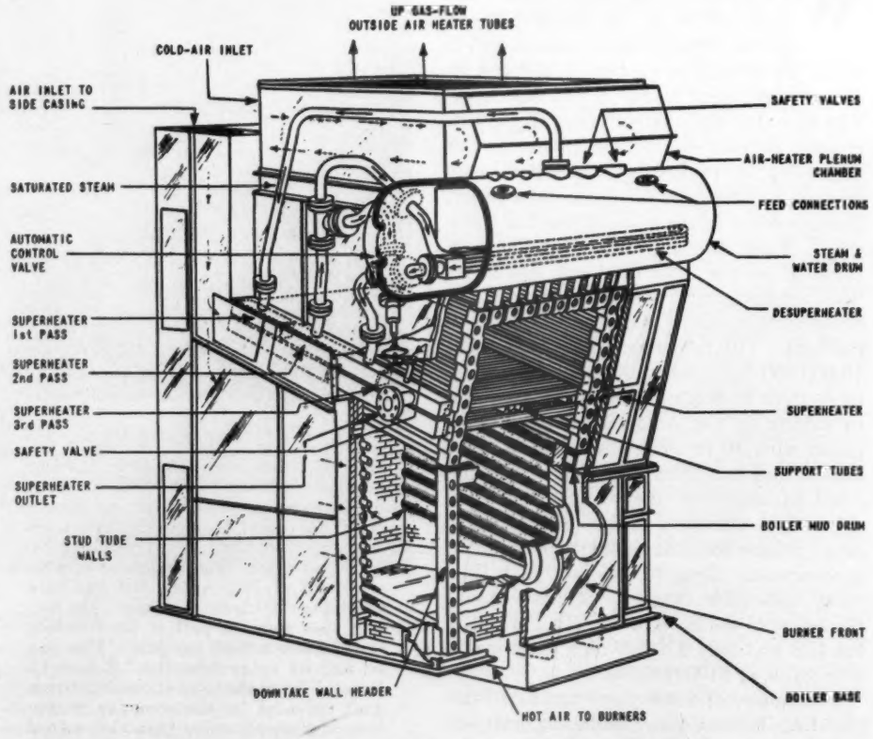
The *J. W. Van Dyke* is named after the chairman of the board of The Atlantic Refining Company in recognition of his interest in its development and his contributions to its engineering phases. The vessel was designed entirely within the organization of the owning company, all studies and preliminary work having been handled by the engineering and construction department under the personal supervision of Lester M. Goldsmith, chief engineer.

The *Van Dyke* has a displacement of 23,898 tons, ranking it among the largest tankers in use. It is 543 feet long over-all, 70 feet wide, and 40 feet deep. Its deadweight carrying capacity is 18,500 tons, and its cargo capacity is 156,000 barrels of petroleum. Its immediate purpose is to transport crude oil; but it has been equipped with the safety features that will permit it to carry gasoline. As crude oil is corrosive and attacks the hulls, it is customary, after a period of years, to convert petroleum tankers into gasoline carriers. As a class, tankers are ordinarily amortized in twenty years; but some of them remain in service as long as 35 or 40 years.

The studies which resulted in the designing of the *Van Dyke* were started in 1930. Prior to that time The Atlantic Refining Company had had extensive experience with both steam- and diesel-driven vessels. It had pioneered several developments in both these classes. Its fleet then included fourteen diesel-electric tugboats and tankers ranging in size from 400 to 3,000 hp. The conclusion reached after operating and observing ships using these two forms of propulsive power was that the diesel engine was unquestionably an economical prime mover for craft up to 3,000 hp. It was the belief, however, that the diesels had definite limitations, and that the high-pressure, high-temperature, steam turbine which was then coming into use in land plants perhaps offered a more efficient means of drive for vessels of more than 3,000 hp. Much thought was given to these considerations during the course of the preliminary investigations looking towards the design and construction of the *J. W. Van Dyke* and a group of sister ships that was to follow. It was not until 1935, however, that a definite conclusion was reached, namely, that small high-pressure, high-temperature turbines are applicable to marine service.

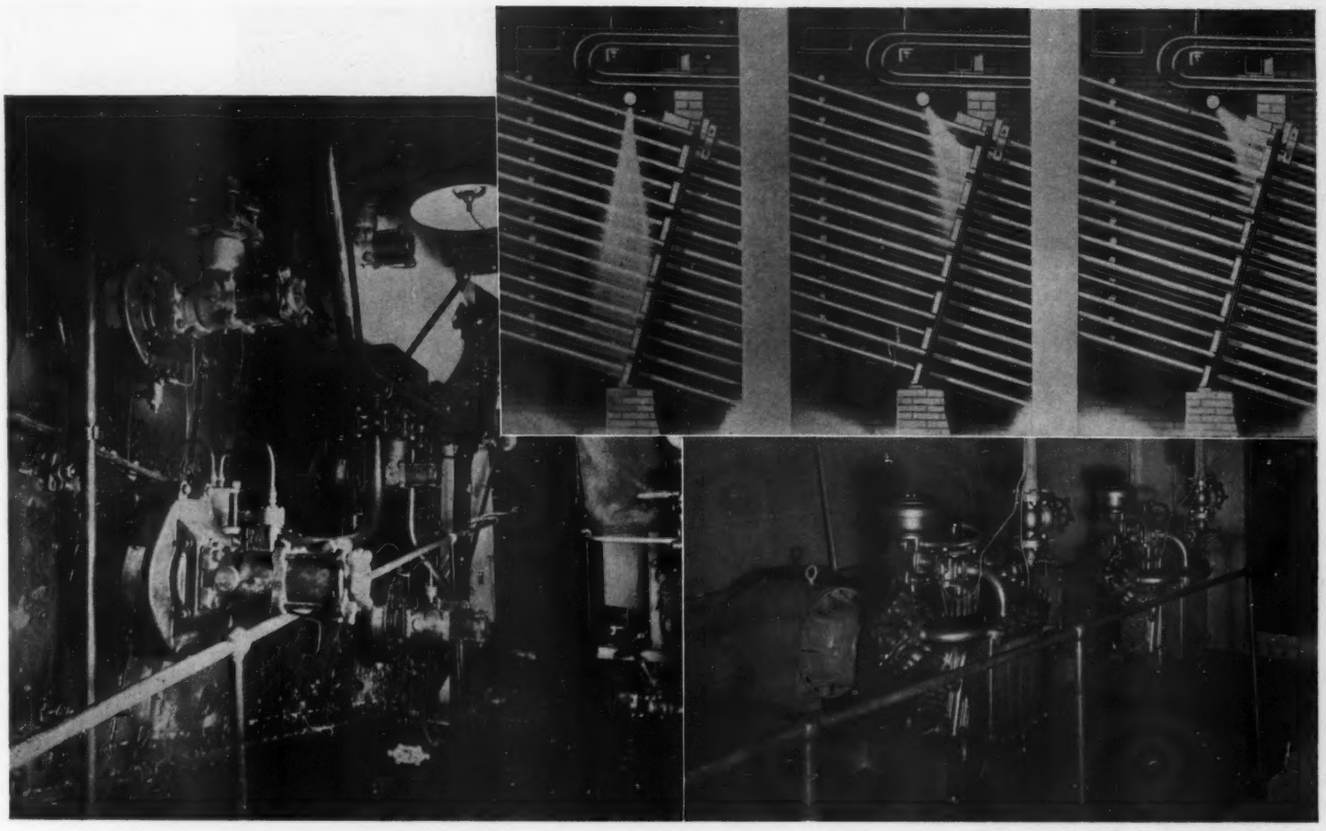
Meanwhile, studies of hull form and propeller design had been made. In other words, the procedure was to determine what size of tanker, as well as outward physical characteristics, would best serve the company's needs, and then to decide what form of power would be most suitable for its propulsion. It was concluded that a tanker having a dead carrying capacity of around 18,000 tons, a length of approximately 520 feet between perpendiculars, a molded draft of about 29½ feet, and an average sea speed of 13¼ knots was desirable. Accordingly, tests were made of model hulls based on those figures. These were conducted in March, 1934, at Hamburg, Germany, which offers the largest and best-equipped tank in the world for that purpose. The experiments showed that the so-called cruiser-type stern was the most satisfactory; and they also made it possible to choose the most effective of two propeller designs that were being considered. As it was not proposed to proceed with construction until two years later, duplicate model tests were run at the U. S. Model Basin in Washington, D. C. These confirmed the Hamburg findings.

From the data assembled, it was computed that 5,000 hp. would be required to propel the vessel at the desired speed; and it was decided that turbine-electric drive would generate this amount of power at the lowest over-all operating cost per shaft horse power. An additional reason for selecting this type of drive was that it would best fit in with the plan to make the tanker discharge her cargo with outstanding rapidity. The company management had requested that the tanker be equipped to discharge its full quota of 156,000 barrels in not more than twelve hours. This called



CUTAWAY SKETCH OF BOILER

Each of the two boilers has a steaming capacity of 22,500 pounds per hour. Feed water is heated to 350°F. in three stages, two ahead of the feed pumps and one after them.



SOOT BLOWERS

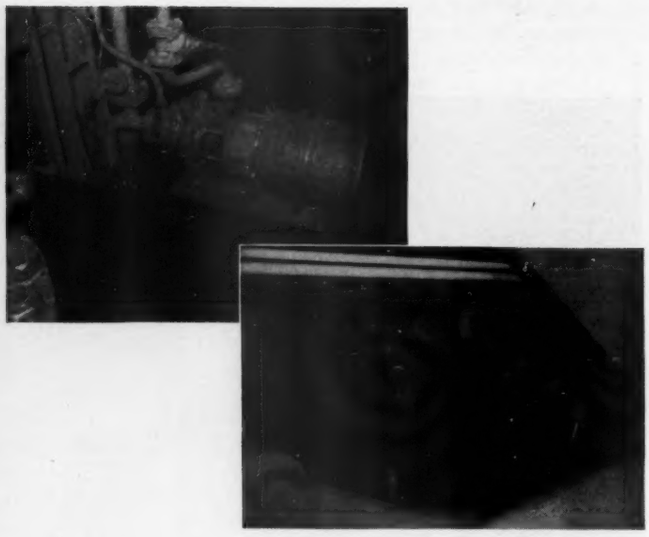
Soot is one of the best heat insulators known, being five times as effective as asbestos. It has been demonstrated that a 1/32-inch film of soot on boiler tubes results in a fuel loss of 9.5 per cent and that a 1/8-inch film increases the fuel bill by more than 45 per cent. Consequently, all efficiently run boiler plants are equipped with devices for blowing accumulations of soot off the boiler tubes at frequent intervals. One of the latest and most economical systems for accomplishing this is the "air-puff" blower developed by the Diamond Power Specialty Corporation. It has been applied to numerous land plants, but the first marine installations are on the new Atlantic Refining Company tankers. Compressed air is introduced through heads outside the boiler wall (left). Each head is connected to a 2-inch element spanning the bank of boiler tubes and having Venturi-shaped nozzles spaced throughout its length in conformity with the spacing of the boiler, superheater, and air-heater tubes. The duration of each puff is about 1½ seconds, and in synchronism with each puff the head rotates the blowing element through an arc of 18°. Accordingly, it requires ten puffs to complete a blowing cycle of 180° when the element is mounted above the tube bank, as shown at the upper right. When the element has tube banks both below and above, it is rotated through 360°, necessitating twenty puffs. There are seven blowers in each of the two boilers: two in the superheater, three in the boiler section, and two in the air heater. Six of the elements puff through a full arc of 360°, and one puffs through only 180°. Therefore, a complete cycle is 130 puffs. The operation is fully automatic. There is a master controller for both boilers that sends electrical impulses to individual solenoid controllers on each boiler. The latter are actuated by the pressure in the supply line. When the air-receiver pressure reaches approximately 110 pounds, the puff takes place, resulting in a drop in receiver pressure to approximately 95 pounds, whereupon the air supply is cut off until the receiver pressure is again built up to 110 pounds. On this basis it takes about two hours to clean a boiler. Thus, if each boiler is cleaned three times every 24 hours, the compressor operates approximately twelve hours out of each 24 for soot-blowing purposes. The compressors are shown at the lower right. They are Ingersoll-Rand Type 40 air-cooled units each mounted with its enclosed, explosion-proof, 15-hp. motor on a structural-steel base.

for pumps that would operate at the rate of 10,500 gpm. It was found that approximately 1,000 hp. would be required to drive these pumps while the ship was in port. The trim of the vessel necessitated locating the cargo pump room amidships. The simplest arrangement by which these conditions could be met was to operate the pumps with electricity produced by a standard turbine generator.

Considerations that entered into the selection of the power plant were stated by Mr. Goldsmith in a paper presented at the annual meeting of the American Society of Mechanical Engineers held last December, and were as follows: "To meet existing rules of the American Bureau of Shipping, the Bureau of Marine Inspection and Navigation, and the requirements of economy in general, it was decided that the turbine should be designed for a pressure of 600 pounds per square inch and a steam temperature of 825°F. When the decision was made to go to this high pressure and temperature, one problem eliminated by the use of motor instead of gear drive was that of the reversing turbine, and the question of keeping it cool.

"In the tabulation of the engineering design of the previous turbine-electric-propelled vessels, both in this country and abroad, it was disclosed that none utilized a generator of standard voltage and frequency as we know them to be standard, thinking of land power plants in this country, nor did they employ the use of alternating current for auxiliary uses as is the case in all land plants. As no reason could be found why other than standard equipment should be used, engineering work was started with the idea of profiting by the principles in use in every modern land power station. A complete heat balance was first worked out in connection with the machinery manufacturers.

"Three bleed stages were decided upon as giving the best compromise between the ideal and practical complications of space requirements and piping. Another consideration borne in mind was that evaporation of feedwater should be reduced to a minimum and that every possible precaution must be taken to protect the boilers from impure water; therefore, all clean drains are



MAIN CONDENSER

The twin, 2-pass unit (left) is bolted directly to the main turbine overhead, with most of its weight resting on spring supports beneath it. It is of the divided type, with a divided hot well so that one side can be shut down if necessary while the other side carries the load with only a slight reduction in vacuum. Above, right, is the 2-stage ejector-jet vacuum pump that serves this unit. The other picture shows one of the Cameron close-coupled pumps that handle condensate.

collected and returned through a cooler into the main condenser while drains which are subject to possible contamination are re-evaporated. The evaporators are planned to float on the line and normally only one of them, operating at much below its rated capacity, will be required. Under sea conditions, the heat of the evaporator vapor is used to supply such low-pressure steam as may be required for general heating purposes throughout the ship, and the remainder goes to the intermediate feedwater heater so that this heat is recovered. An emergency vapor line to the condensers is also provided for port use; but, with proper operation, this should not normally be necessary.

"All three boiler feed pumps are turbine-driven. Only one is required for normal operation. The exhaust is added to the second-stage bleed. Therefore, it will be noted that under normal conditions the heat from the evaporator vapor and the feed-pump exhaust is either recovered in the feed or otherwise usefully employed. No heat which can be put to use is rejected to the sea water except under unusual conditions."

From advance calculations, it was expected that an over-all heat efficiency from burners to shaft of 22.5 per cent would be obtained, this figure applying only to fuel entering into the propulsion cycle. During the trials, efficiencies as high as 22.6 per cent were obtained, and in actual operation this figure has been increased to 22.7 per cent.

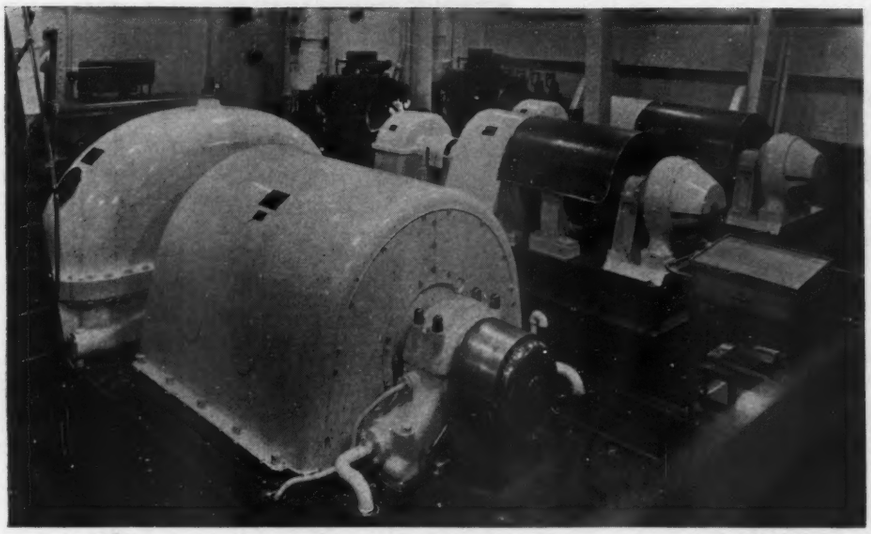
Steam is supplied at 650 pounds pressure and at a temperature of 835°F. by two Babcock & Wilcox cross-drum, header-type, marine water-tube boilers. Each has a steaming capacity of 22,500 pounds per hour. They employ air preheaters and have fully automatic combustion and superheat control. Combustion control is used in conjunction with meters, while the superheat control depends solely upon automatic devices which are being utilized for the first time aboard ship. Because the existing rules of the Bureau of Marine Inspection covering high-pressure piping prohibited welding and contained no provisions for handling steam at temperatures higher than 750°F., special rulings had to be obtained to permit the use of stress-relieved welded joints. All the high-pressure steam piping is of carbon-molybdenum steel. The main turbine generator is located at the same level as the steam header from the boiler, an arrangement that eliminates lengthy piping. As a result, the piping is short and simple, more than the usual amount of space is provided around all machinery, and the engine room, accordingly, does not present the crowded appearance that it ordinarily does aboard a vessel of this type. The white enamel and the chromium finish of all machinery and stainless-steel ladder railings enhance the attractiveness of the room.

The main turbine generator develops 4,500 kw. of 60-cycle, 2,300-volt current at 3,600 rpm. when supplied with steam at 600 pounds pressure and 825°F. maximum temperature and with the exhaust at 28.5 inches of mercury vacuum. The turbine is of the impulse type, having fifteen stages, with bleeds after the third, seventh, and twelfth stages. The propulsion motor is an air-cooled, synchronous-type unit which delivers 5,000 shp. at 90 rpm. Both the motor and the main generator are equipped with carbon-dioxide connections for fire protection.

Each of the two auxiliary turbine-generator sets, one of which is a spare, consists of a geared turbine driving a 350-kw., 60-50 cycle, 450-volt synchronous generator, a 65-kw. exciter for the main generator, and a 20-kw. exciter for the auxiliary generator. All engine-room auxiliaries are driven by explosion-proof, alternating-current motors. These and all other underdeck motors are entirely inclosed.

When the tanker is at sea and running at 90 rpm., the main turbine generator supplies power for running all auxiliaries, the 2,300-volt current being stepped down to 440 volts by transformers of special design. When the propeller speed drops below 85 rpm., the auxiliary turbine generator automatically takes up the 440-volt load for auxiliary power. Upon the return of the propeller to the synchronous speed of 90 rpm., the main generator again furnishes 440-volt current and the auxiliary sets automatically become synchronous motors and run only as exciters for the main generator.

Ingersoll-Rand 2-pass condensers serve both the main and the auxiliary turbines. The main condenser has a condensing capacity of 35,300 pounds of steam per hour at a vacuum of 28.44 inches of mercury when using sea water at 76.8°F., which is the average temperature for the conditions under which the vessel operates. It has 4,775 square feet of tube surface, or 1.05 square feet per kilowatt, which is a very low figure compared with the accepted standards for marine condensers a few years ago. The tubes are of 70–30 copper-nickel alloy, and are ¾ inch in diameter and 14 feet long. Bellows-type expansion elements in the



TURBINE-GENERATORS

At the left is the main 4,500-kw., machine, with the two 350-kw. auxiliary units at the right. All were built by General Electric Company. Steam is supplied at 650 pounds pressure and 835°F. temperature. As the latter figure is just below the dull-red heat of ordinary steel, special alloys of high-creep strength were used in these units.

shells relieve the strains set up at different rates of expansion in the tube nest and in the shell. The auxiliary condenser is a 2-pass unit with 800 square feet of tube surface and has a condensing capacity of 6,000 pounds of steam per hour under the same conditions as those given for the main condenser.

The tubes in both condensers are of the same material, diameter, and length so that one set of spares suffices for both. Each condenser is served by a 2-stage air-ejector unit, complete with an inter- and after-condenser. The main condenser is divided to permit shutting down either side, with a slight reduction in vacuum, in case a leaking tube must be repaired. As it has long been recognized that entrained air in the circulating water is one of the chief causes of corrosion in condenser tubes, steps were taken in this instance to remove the air before the water reaches the circulating pumps. This is done by running the sea water into a chamber provided with baffles. After six months of operation, the condenser tubes had shown no signs of attack, indicating that the air was being effectively removed. Mr. Goldsmith has applied for a patent on this air separator.

Compressed air is supplied by two Ingersoll-Rand Type 40 air-cooled compressors each of which delivers 60 cfm. at 120 pounds discharge pressure. They are driven by 15-hp. motors. The requirements for air are such that one machine must be run almost continuously, and the practice is to alternate the two units on each one-way voyage.

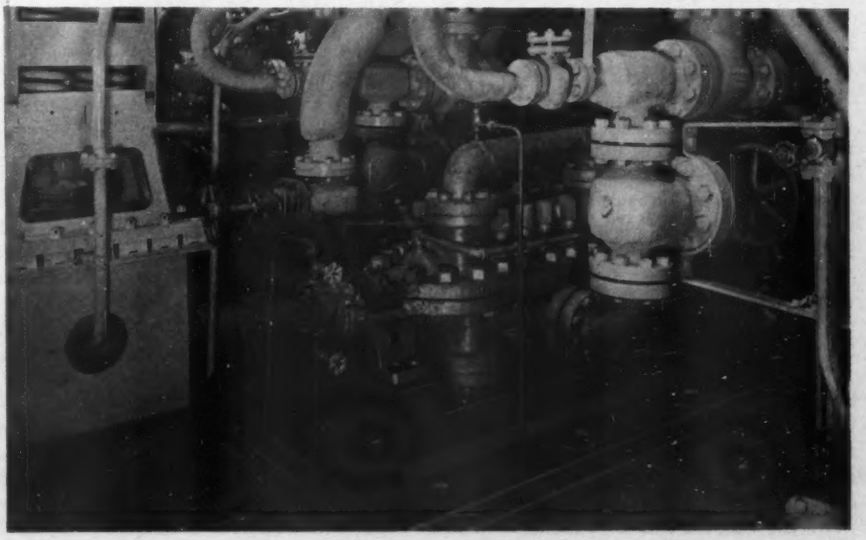
The greatest individual use of air is for cleaning the boiler tubes with automatic "air-puff" soot blowers made by the Diamond Power Specialty Corporation. Although it is comparatively new, this type of blower has been installed in a number of land power plants, but this marks its first application in marine service. The cleaning of the boiler tubes aboard ship is ordinarily done with steam, but the new air-operated system was adopted in this instance to save steam and to take advantage of the greater over-all economy it offers. As all boiler-feed water must be distilled aboard the vessel, the importance of conserving steam will be apparent. When steam-operated soot blowers are employed, approximately two-thirds of the steam required goes up the stack and is wasted, so a substantial saving is effected by using "air-puff" blowers. A description of the equipment and how it works is given in connection with accompanying illustrations. Another important application of air is the operating of valves incorporated in the automatic combustion-control system. Various pneumatic tools, paint sprays, etc., also are employed for maintenance and repair work, and a whistle is blown with compressed air.

The steering gear is of the electric-hydraulic type, and all deck machinery is electrically operated. An electric-hydraulic anchor windlass is equipped with a by-pass valve in the hydraulic system that opens when the load exceeds a given point, thus preventing overloading of the motor when the anchor is snagged.

In specifying the cargo-discharge pumps for the tanker, great stress was placed on the desirability of unloading it during the interval between high tides, thereby reducing the "turn-around" time in port. The capacity of the 3-stage, deep-well, centrifugal pumps is sufficient to unload the 156,000 barrels of oil in 10½ hours, although this has been accomplished in 9 hours and 21 minutes.

It is interesting to note that the adoption of turbine-electric drive for the *Van Dyke* instead of the more conventional gear drive has added from 1,000 to 2,000 barrels to the cargo capacity. The total machinery dead weight is 423 tons, of which 405 tons is made up by the power plant and auxiliaries. The latter figure is equivalent to 0.08 ton per shaft horse power, which is usually from 0.11 to 0.12 ton for a geared-turbine ship of equal size and from 0.11 to 0.14 ton for a direct-diesel or a diesel-electric.

In the eighteen months the *J. W. Van Dyke* has been in service, she has fully lived up to the expectations of the designers and has shown power-plant efficiencies not previously approached in marine installations in this country.

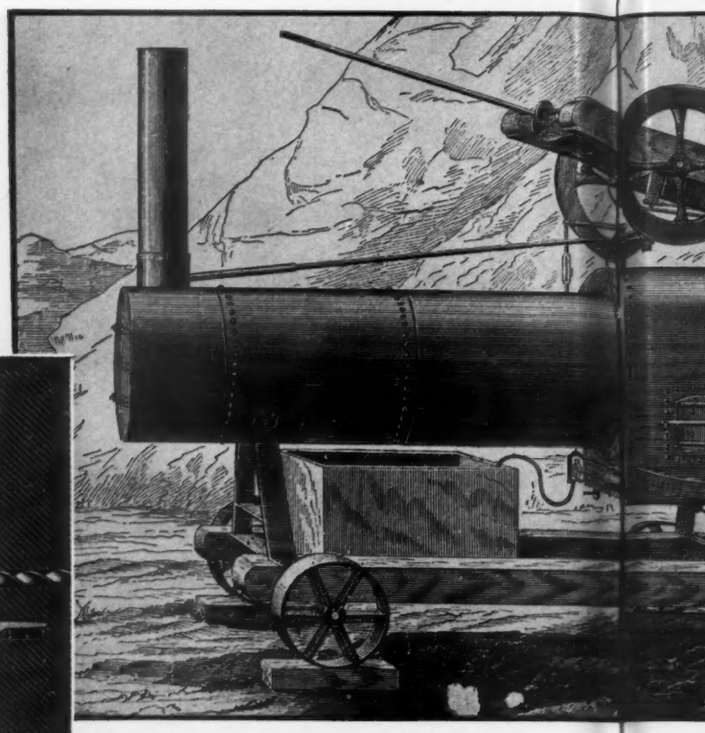


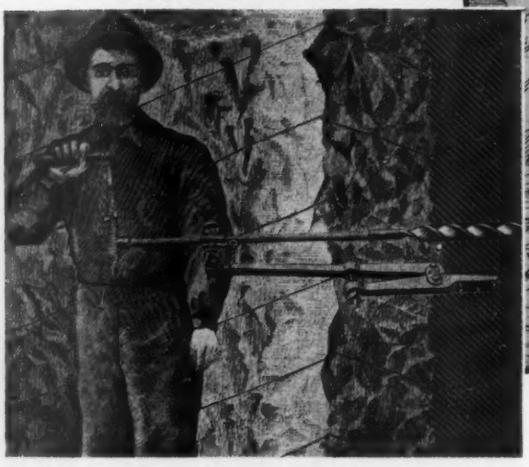
BOILER-FEED PUMPS

There are three of these Ingersoll-Rand 8-stage centrifugal units, each delivering water at 270°F. at the rate of 125 gpm. against 755 pounds pressure, which is equivalent to a head of 1,860 feet. Each is driven at 3,600 rpm. by a 125-hp. steam turbine. Only one pump is normally required.

Rock Drill a Product of Persevering Development

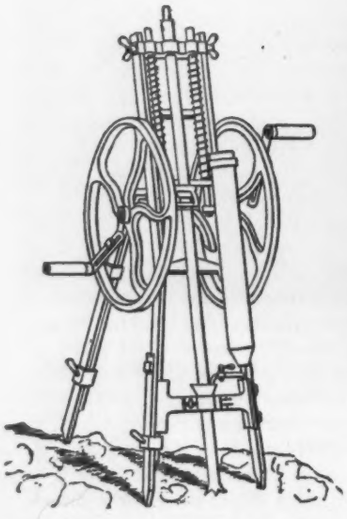
Copeland Lake





THE HOWELLS DRILL

This hand-cranked machine was used considerably in coal mines, and was also employed for drilling some soft rock. It was fastened to the face being drilled by means of the device shown.



HAND-POWER DRILL

This illustration of a Victor drill was taken from Appleton's "Cyclopedia of Applied Mechanics" published in 1879. The turning of the wheels caused cams to lift the drill steel against the heavy springs, the recoil of which propelled the steel against the rock.

ONLY seventy-eight years have elapsed since the first practical mechanical rock drill was introduced, and yet those years have brought an advance in the effectiveness and economy of rock drilling that exceeds by a thousandfold all the progress that was previously made. Prior to the middle of the past century, all the improvements in rock excavating had one objective—that of increasing the effectiveness of human labor, for muscle power was the only kind of power that had then been harnessed for such work.

Flinders Petrie and other investigators have told us how ancient peoples quarried rock for their edifices and hollowed out tombs by unbelievably slow and tedious methods. Tubular drills, crude saws, and other primitive tools, all of them hand powered, were the sole implements at their disposal; and only the abundance of human labor available under the existing slave system made large-scale excavating undertakings feasible.

With the discoveries of methods for making steel and gunpowder, the technique changed. The hammer and the chisel became the principal tools of the miner, the stone producer, and others who had to break rock. Nevertheless, the emphasis was on labor. And where the efforts of so many men were required, the only possible way to keep production costs down was to enforce a low-wage standard.

The first step in the development of mechanical drills was the substitution of a spring or springs for the hammer swing. Human muscles still served to turn the wheel that put the spring in tension, after which its recoil propelled the drill steel against the rock. This type of apparatus had its drawbacks: it entailed laborious work, and it was readily adaptable only to down-hole drilling. In 1838 the Singer brothers, one of whom was later to attain fame as the inventor of the sewing machine, improved on this scheme by employing a steam piston to elevate a heavy drill steel which was then allowed to drop by gravity. Eleven years later, the ponderous Couch drill, mounted on top of a boiler, was devised. Its action was to throw the drill steel against the rock face, making it a punching machine, and there was no provision for rotating the steel between blows.

The first mechanical drill that bore any resemblance to modern machines was patented in 1851 by J. W. Fowle. In it the drill steel was clamped to the piston rod. It had mechanical valve motion and automatic rotation of the steel, and seems to have been the first machine embodying the principal features essential to successful rock drilling. Fowle's drills were introduced in the 8-mile Mont Cenis railroad tunnel in France in 1861. They aided materially in expediting the driving of that bore; but there is no record that they were used extensively elsewhere. In 1851, also, the Cavé drill was patented in Europe. It was a piston-type drill that could be operated with either compressed air or steam. Both valve motion and rotation were effected manually, and the action of the machine was, consequently, slow and uncertain.

The decision, in 1856, to drive the Hoosac railroad tunnel in Massachusetts stimulated the minds of American inventors, and the Burleigh drill was produced by Charles Burleigh, John W. Brooks, and Stephen F. Gates. It was a modification of the Fowle machine, and about 40 of them entered service in the Hoosac Tunnel in 1866. Burleigh redesigned the drill in 1868; and the new models, aided materially by the use of nitroglycerin which had been patented in the United States a year previously, helped to finish the tunnel in 1873.

In 1871, Simon Ingersoll obtained a patent on a rock drill and also on a universal tripod mounting that considerably increased the application of mechanical drills. The Ingersoll Rock Drill Company was organized the same year. It obtained the patents of Fowle and Burleigh by purchasing the Burleigh Rock Drill Company, and the best features of the Burleigh and Ingersoll machines were incorporated in a new design known as the Ingersoll "Eclipse,"

THE COUCH DRILL

The machine at the left was the first mechanical rock drill built. It was patented March 27, 1849. There is no record that it was ever employed extensively.

BURLEIGH DRILL

The Burleigh drill was devised for use in the Hoosac Tunnel and was the first practical drilling machine applied in America. Its best features and those of Simon Ingersoll's first drills were combined in the Ingersoll Drill Company machines which were put into production in 1871.

INGERSOLL "ECLIPSE"

Henry C. Sergeant improved upon Simon Ingersoll's invention and contributed the "Eclipse" valve that gave the machine its name. The tripod mounting, important in making drills more effective, was the work of Ingersoll alone.

which was the first unit to be widely employed in general drilling work. Henry C. Sergeant, who designed the "Eclipse" valve motion, was the moving spirit in the Ingersoll organization until 1883, when he sold his interest and went to Colorado to engage in silver mining. A year later, however, he conceived the idea for a new valve motion, returned East, formed the Sergeant Drill Company, and opened a factory in Bridgeport, Conn. In 1886, the Ingersoll and Sergeant concerns combined.

Meanwhile, the Rand Drill Company had been making headway in the mining industry with a drill that was probably largely the work of J. C. Githens, an able inventor. Albert T. Rand, the oldest of three brothers, was in the powder business, and saw in the power-driven drill a machine that would drill larger holes than those possible by hand methods and that would, therefore, permit a larger charge of explosive to be placed at the bottom of the hole where it would do the most work. He prevailed upon his brothers Addison C. and J. R. Rand to enter business with him, and in 1873 they began making drills. Their "Little Giant" drill, with a tappet-operated valve, came into widespread use in mines, the Ingersoll and Sergeant companies having concentrated more on open-cut work, quarrying, and tunnel driving. In 1905 the Ingersoll-Sergeant and Rand interests became the Ingersoll-Rand Company.

Meanwhile, J. George Leyner had invented the hammer drill, which applied mechanically the principle of hand drilling. His was the first machine to use hollow drill steel, which made it possible to convey air or water, or a mixture of both, to the bottom of the drill hole to aid in removing cuttings. In 1911, Ingersoll-Rand Company acquired Leyner's patents, and two years later placed on the market the first "Jackhamer," forerunner of all self-rotated hand-held drills. It is interesting and significant to note that, in this one company, there have come together virtually all the important ideas that led to the development of today's rock drills. Since Leyner's contribution to the art of rock drilling there have been no revolutionary changes in the design of drills; but there have been continual improvements and refinements which have, collectively and cumulatively, greatly increased the effectiveness of present-day models.

Although it has taken three-quarters of a century to produce the rock drill as we now know it, it seems that most of the qualifications of a good drill were known long before the inventive minds were able to produce one. In the 1830's, two men, André and Drinker, listed the characteristics of a good mechanical rock drill, as follows:

1—It should be simple in construction and strong in every part.

2—It should have few parts, especially moving parts, and all parts should be easily renewable.

3—It should be as light in weight as it can be made and still possess the required strength.

4—It should occupy little space.

5—The striking part should be of relatively great weight, and it should strike the rock directly. (Piston drills were based on this principle, but in the hammer drill the piston is relatively light and depends upon velocity to obtain the required force. Furthermore, in the hammer drill the piston and drill steel have been separated, and in the piston drill the punching action has been supplanted by a hammering effect.)

6—No other part than the piston should be exposed to violent shocks.

7—The piston should be capable of working with a variable length of stroke.

8—The sudden removal of resistance should not be liable to cause damage to any part.

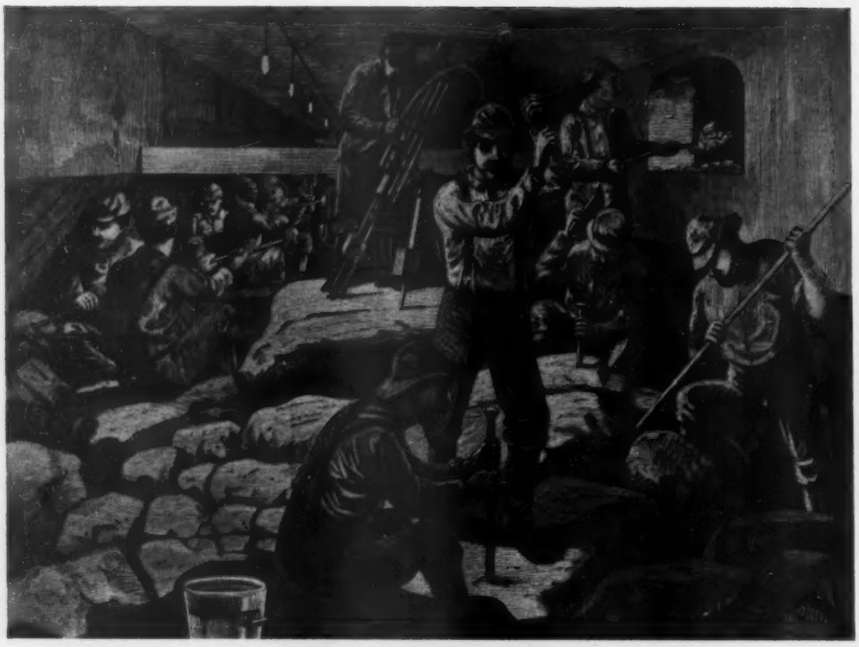
9—The rotating motion of the drill steel should take place automatically.

10—The feed, if automatic, should be regulated by the advance of the piston as cutting advances.

11—The machine should be capable of working with a moderate degree of pressure.

12—It should be capable of being readily taken to pieces.

Those who are familiar with modern rock drills will recognize that these specifications have been more than fully met, for the application of the hammer principle makes for a far more effective and quicker-acting tool than it was possible to visualize when André and Drinker projected their ideas.



HAND AND MACHINE DRILLING

This reproduction of an illustration that originally appeared in the "Scientific American" of April 16, 1887, shows what is reported to have been the first power drill ever operated in a caisson under air pressure. The scene was beneath the Harlem River, New York, where excavating was in progress for the piers of the Washington Bridge. Note that most of the drilling was still being done by hand.

The development of present-day efficient drills has been a slow and sustained one. For every new model that has reached the market, probably ten to twenty machines have been designed, manufactured, and discarded when tests revealed some shortcoming. Fifty years ago, William Lawrence Saunders wrote: "The rock drill embodies more inventions for its volume and weight than any other machine of equal importance." This was true then, and it is true today, for the scope of the efforts to improve the rock drill has materially broadened in the past half-century. Millions of dollars have been spent on research; and instead of relaxing now that a high degree of efficiency has been reached, manufacturers are redoubling their efforts to bring about additional improvements. Someone has said that "the permanent work of this world is done by persistent and steady upbuilding," and it is certain that the modern rock drill was produced in this way. Mechanically minded though we are, it probably would be impossible to start afresh and attain the present stage of development short of a good many years. This is so because most of the important things about building better drills have been learned through experience, and experience cannot be gained overnight.

Rock drills have made it possible to pyramid the manual effectiveness of labor. At the same time, they have improved the lot of the laboring man and of society in general. With his hands alone, a man can produce only so much work and, accordingly, can expect to receive only a meager wage. With an efficient machine, his productivity is multiplied many fold and his employer can afford to pay him more for his efforts.

The rock drill has greatly increased the opportunity for employment, for it has made profitable and expedient many operations that could not be carried on if drilling had to be done by hand. Steel, copper, lead, zinc, and all other base metals that are so vital to our comfort and progress can be used generously because the rock drill makes it possible economically to mine the ores from which they come. The same is true of building stone and of all other products of nature that require the breaking of rock for their exploitation. Even gold and silver and other precious metals could be won only from extremely rich lodes if drilling still had to be done by hand. Low-grade deposits would lie undeveloped.

Without the rock drill, construction would lag because of the great expense involved. The building of dams and tunnels for the irrigation of land and for the generation of low-cost power could be but sparingly undertaken. Railroad tunnels and subways would be too expensive to construct; and it would be virtually impossible to remove the rock from ocean and stream beds to provide channels for the navigation of large boats. Scores of similar examples might be cited.

The modern rock drill is a reliable and durable machine. During the drilling of the Hoosac Tunnel there were three drills in the repair shop for each one in operation. At the St. Gothard Tunnel, machines became disabled or worn to the point where they could no longer be used after 24 hours of service. Better design and the development of more resistant metals have made the drill of today a dependable unit, despite the fact that it does many times more work than did the earlier models.

This matter of durability is a very important one from the user's standpoint. Of itself, the maintenance of drills—meaning the cost of the labor and spare parts required to keep them running efficiently—amounts to considerably less than 1 per cent of the total operating cost of a mine. Consequently, it is not of vital concern; but delays in production resulting from drill failures have a pronounced effect in increasing operating costs. Realizing this, rock-drill manufacturers strive to build long life into their products. In the case of Ingersoll-Rand Company, intensive research is always in progress with a view to improving essential drill parts.

MODERN DRIFTER DRILL

The DA-35, the most powerful of a new line of Ingersoll-Rand drills that is designed to meet the demand for an economically operating machine of high drilling speed and durability. It weighs approximately 150 pounds.

Portable Indicator Detects Combustible Gas

TESTING FOR GAS

Above is shown an operator carrying a J-W indicator into which he is drawing samples of atmosphere from one of a series of holes drilled in the pavement to locate a leak in a gas line. At the right is a close-up of the indicator, which weighs only 6¼ pounds complete with batteries.

IN MANY branches of industry the detection of combustible gases is an imperative safety precaution. Apparatus for making tests of the atmosphere have been developed to a high degree of reliability and accuracy. Johnson-Williams, Ltd., of Palo Alto, Calif., which has been making such equipment for twelve years, has recently announced a new, portable gas indicator that is smaller, lighter, and less costly than previous models but retains their essential features. Known as the Model F J-W Combustible Gas Indicator, it weighs only 6¼ pounds and measures only 3¼x7¾x6 inches.

Gas indicators are employed by gas companies, oil companies, and various industrial plants that store, transmit, or handle explosive gases or liquids. Before men are permitted to do any work around tanks or equipment which contain or have contained such fluids, it is common practice to test the atmosphere. This is particularly true where the work involves the use of torches or hammers, chippers, wire brushes, or similar tools that might cause sparks. The most familiar application so far as the general public is concerned is that of testing for leaks in underground distribution systems by gas companies.

The J-W indicator is an electrically actuated device that gives a direct meter reading of atmospheric samples that are drawn into it. A common rubber bulb serves as an aspirator to collect the samples. Where the operator cannot conveniently or safely enter the zone to be tested, the sample is drawn into the indicator through flexible metal tubing of suitable length.

When a mixture of air and combustible gas or vapor is brought in contact with a hot platinum wire, a rapid combination of the combustible with the oxygen of the air is effected at the surface of the wire. This raises the temperature of the wire and increases its electrical resistance. In the J-W indicator this change in resistance is made to actuate a sensitive meter. The reaction chamber and filament are so designed that an increase in the concentration of the combustible results in a proportionate increase in the resistance of the platinum wire. Consequently, the amount of combustible present is indicated directly by the meter.

The meter scale has a yellow or "dangerous" range, and a red or "explosive" range. The dangerous section begins at 0.2, which represents a content of about 0.3 per cent of gasoline vapor by volume. A factor of safety of 5 is allowed with respect to the lower explosive limit, this being considered essential in the case of containers on which any welding or other "hot" work is to be done. The explosive point, 1.0, represents the leanest mixture that will burn or explode if ignited. If the vapor sample is too rich to explode, the indicator hand will first swing sharply to the red end of the scale and then fall back to zero, giving no further indication. Current is supplied by batteries, and a second meter registers when the current is turned on and is used for controlling the correct voltage across the filament.

Compressed-air equipment is frequently employed on undertakings associated with such indicators. In a city, for example, where gas accumulates in a manhole, a routine leak survey discloses it and the problem then is to determine the location of the break in the main. A series of holes is drilled in the pavement along the line of the gas pipes, and readings are taken in each one. The highest flow rate identifies the hole nearest the leak. Additional, closely spaced holes are put down in the immediate vicinity, and more readings are taken. This procedure spots the leak so accurately that a crew seldom misses it even with an excavation barely large enough to permit making the repair. Where work is being done in plants, tank ships, storage tanks, manholes, etc., and readings show that a hazard exists, the space is usually blown out with compressed air and thus rendered safe for any operation.

In J-W indicators the filament unit is built as a pair of identical coils one of which is the active filament and the other a balancing coil. This compensates for ambient temperature, and gives accurate and stable readings as soon as the current is turned on. A flame-arresting system prevents the passage into the instrument of any air-gas flame.

FOR MAINTAINING PLANES

The Taca shops in Tegucigalpa, Honduras, are modern and completely equipped to do just about anything in the line of repairing or of rebuilding planes. As at most flying-machine bases, much of the work is done with air-operated tools. Shown here are men using Ingersoll-Rand multivane drills and, below, one of the four Type 30 air-cooled compressors that supply the air requirements.

Aerial Freighters Solve Jungle Transport Problems

TRANSPORTES Aereos Centro-Americanos, better known as Taca, is one of the world's largest carriers of aerial freight. It operates in the five countries of Central America and hauls just about everything from air compressors to live poultry, the only restriction being that single pieces must not weigh more than 4,000 pounds. In addition, it carries passengers, mail, and express.

The story of the remarkable growth of Taca constitutes a 1-man business romance, and is of such interest that it was told in detail about eighteen months ago in *The Saturday Evening Post.* The man concerned is Lowell Yerex, a native of New Zealand who was educated in the United States and who flew for the British R. F. C. during the World War. Upon his return to America he became a barnstorming flyer, made money at it, and settled down to the prosaic existence of an automobile-agency manager. He lost on the ground the money that had come from the air; and in 1931 he arrived in Honduras with a small cabin plane and $25. He immediately saw and set out to fill the need for a chartered air service. From that beginning as master of a sky ferry he has progressed at a dizzy pace to the head of a company that flew 8,000 tons of freight over jungles and lofty mountains last year. Taca now has nearly 60 airports scattered throughout the banana belt; and the concern is doing more than $1,000,000 worth of business annually.

The rise of such an organization in so short a time has been made possible by the physical nature of the region that is served. Dense vegetation, mountains, and unruly streams combine to create a real transportation problem. The building and maintaining of roads is virtually prohibitive, considered from an economic standpoint; and until aircraft came to the rescue, pack mules did most of the heavy hauling. The weight limit of individual parcels was 100 pounds. Now, freight that formerly required two weeks for delivery from the coast to the interior is flown in in less than two hours, and this is making it feasible to operate mines and other industrial enterprises that had no chance of existing before.

Of late, the aerial service has been extended to the chicle-growing area of the Peten section in Guatemala. Chicle is produced from the sap of the sapota tree and is the principal ingredient in chewing gum. The Peten district covers 15,000 square miles, yet it is so densely overgrown that only 7,500 persons live there. Chicle is gathered by contractors and shipped to the outside world. In the past, 20 mules were needed to carry out 4,000 pounds of chicle, with other mules to transport supplies for men and beasts during a journey that took anywhere from two weeks on up, depending upon weather conditions. Today, an airplane picks up the 4,000-pound load at an airport built at the foot of the ruins of the famous Aztec palace and temple at Uaxactun and delivers it at Puerto Barrios, on the Atlantic coast, in less than two hours. On the inbound flight it transports building supplies, food, and machinery.

Taca uses tri-motored Ford monoplanes, of which twenty have been purchased from air lines in the United States, reconditioned, and the necessary body changes made to fit them for freight-carrying. These craft also have been used for much of the aerial freighting done in South America by Pan American Airways. Although too slow to satisfy present-day passenger schedules in the United States, they are still of lightning speed compared with mules, and their dependability and sturdiness fit them well for their role of dray horses of the air.

It will be readily apparent that the remoteness of the region served from any center of machinery production makes Taca dependent upon its own resources so far as maintenance is concerned. Accordingly, complete shops have been established at Tegucigalpa, Honduras. They are staffed and equipped to build a plane if this should become necessary, and all repairs are handled both quickly and effectively. Air-powered tools are essential to this work; and the company operates four Ingersoll-Rand air-cooled Type 30 compressors to supply the air. Chief Engineer Charles E. Mathews directs the shop operations.

AN ENGLISH CHANNEL TUNNEL

AS POINTED out on this page in May, the threat of war is causing the British Isles to honeycomb the ground with shelters designed for the protection of civilians during air raids. Another manifestation of the same primordial instinct to dig in when attack seems imminent is the revival of serious discussions relating to a tunnel underneath the English Channel. The French and British governments are going over proposals presented by their respective engineers; and if the long-talked-of bore is driven it will very likely be a joint undertaking by the two nations.

Most of the previous channel-tunnel schemes were motivated by the desire to facilitate peacetime traffic and trade between the two countries. The present vital consideration, however, is the strategic value of such a passageway in landing British troops and armament in France without serious hazard or interference. From the data thus far assembled, it is estimated that the tunnel would cost approximately $132,000,000. Working independently of the government officials is the Channel Tunnel Company, a French concern, that is collecting essential information with a view to convincing the British and French peoples that a tunnel is a vital necessity.

A COLLIERY-HORSE SHOW

IN AN effort to dispel the belief that horses employed underground in collieries are mistreated, the Mining Association of Great Britain early this month exhibited representative animals at the Royal Agricultural Society's Centenary Show at Windsor. Many of the leading coal-producing companies of the nation participated, and a total of 90 "pit ponies" were shown. They ranged in height from 9 to 15.2 hands, in age from 5 to 27 years, and in length of underground service from 6 months to 23 years.

Scrapers, conveyors, and other forms of mechanical apparatus are fast replacing horses in English mines and mules in American mines, and such replacements have, in general, considerably reduced production costs. However, there are places where physical conditions favor a method of working deposits that involves the aid of animals. In England, some 33,000 horses and ponies are still employed underground, and a Pit Ponies' Protection Society has been organized in an effort to terminate their services. Propaganda takes the form of asking consumers to refuse to purchase coal from any colliery in which horses are used. The colliery operators countered by arranging an annual show at which the people may observe the condition of what they claim to be representative animals. One of the most interesting results was the demonstration of the fact that the general impression that horses go blind from working underground is a fallacy.

TRANSVAAL LABOR SUPPLY

ONE of the chief difficulties of the South African gold-mining industry is that of obtaining a sustained and ample supply of native labor. With gold at its present high price, there has been a marked increase in its mining. Not only have established mines stepped up production but new properties have been opened and are pushing development work at a rate that is rapidly demanding larger labor forces.

Last year the total native-labor strength of all the mines was almost 340,000 men. Under the system in use, the natives are periodically returned to their home communities as a health safeguard. There they engage in agriculture and other pursuits; and if the year is a favorable one for crops, many of them decide to remain rather than return to the mines. It is therefore necessary to recruit men to replace those that drop out and also to meet the rising demand for workers.

Last year 293,000 natives were distributed among the gold mines, but there was a shortage of help at most properties. It is estimated that the number of natives available will have to be increased by 5,000 a month for a period of two years to bring the mines up to full working strength. The enlistment of additional workers is carried out by the Native Recruiting Corporation. One means of augmenting the supply is to employ a limited number whose physique is below the requirements for underground service. These are given lighter jobs on the surface. By providing them with wholesome food and enough of it, and by giving them medical attention, it has been found that a large percentage of these men improve in condition to the point where they are able to work underground. Since this scheme was put into effect, 4,100 men of this class have been hired.

In the past, the natives have been recruited almost entirely from the temperate zones; but the shortage has led to the employment of many so-called tropical natives from areas north of latitude 22° South. Indications are that these men are becoming well adapted to the change in climatic conditions. The death rate from disease among them was reduced from 18.18 per 1,000 in 1937 to 8.6 per 1,000 in 1938. The greatest improvement shown was in the death rate from pneumonia, which dropped from 10.25 to 3.41. This notable decrease is attributed to the use of a new medicine, benzylsulphanilamide. At the end of 1938, the tropical natives employed numbered 16,332.

Natives with past service are at present permitted at the time of their reëmployment to select the mine in which they desire to work. This results in a somewhat inequitable distribution, and in order to correct this it will, it is believed, become necessary to allocate the men to the different properties on the basis of their respective production tonnages.

Diamond-Impregnated Saws for Stone-Cutting

AS MENTIONED previously in these pages, the diamond producers of South Africa are conducting extensive researches with a view to widening the field of usefulness of stones of non-gem quality. These industrial diamonds, or bort, make up two-thirds of the annual output of approximately 10,000,000 carats. One development that shows signs of promise is the diamond-impregnated wheel for cutting dimensional stone. It is claimed that wheels of this kind will cut stone faster than any other equipment; and they have already been applied to various classes of work.

The smaller wheels, up to 6 or 8 inches in diameter, are used in connection with hand-operated pneumatic tools. Larger ones, up to 6 feet in diameter, are incorporated in conventional stone-sawing machines and are driven by any suitable form of power. They are mounted in a fixed position, and the stone is fed to them. In the smaller wheels, the entire face of the rim is impregnated with diamonds. The larger ones have sockets, at intervals, of either steel or alloy steel impregnated with crushed diamonds, the whole being fused to bind the mass together firmly and thus to minimize the loss of diamonds through abrasion. In all cases, water is supplied to the cutting face to wash away the abrasive cuttings.

It has been suggested that small, air-operated saws of this type might be used to advantage in taking samples of ore in mines. Representative sections of a vein could be obtained by this method, and there would be no tendency towards concentration of the metallic content of the sample. For preparing rock specimens for microscopic examination, the Diamond Development Company has produced a small saw with a diamond-impregnated rim 0.004 inch in thickness. It is operated by a 3½-hp. motor and attains a peripheral speed of 10,000 feet a minute. By means of it, sections only one millimeter thick can be cut from the hardest rock.

TAPPING A GLASS-MELTING TANK

This picture shows an improved method adopted in a large glass-manufacturing plant for tapping a melting tank to withdraw the molten glass left in it after a run. The workman is in a pit beneath the tank and is operating an Ingersoll-Rand SAR-85 stopehamer. By employing a long steel he is able to remain on the floor below in a comparatively cool zone, although the temperature near the floor may be as high as 130°F. He is protected by a suit, helmet, and gloves of asbestos. Prior to the use of this equipment, it was the practice to tap the tank with a "Jackhamer." This necessitated building scaffolding in the pit for the man to stand on. As he was working directly under the tank, the heat was very great and there was an element of danger that does not exist under the present arrangement.

Ice-Cooling of Concrete was Considered for Boulder Dam

A PROPOSED scheme of cooling the concrete in a high dam in the Harz Mountains of Germany by supplying the water for concrete-mixing in the form of crushed ice was mentioned in our March issue. It is now divulged by R. F. Walter, chief engineer of the Bureau of Reclamation, Denver, Colo., that the same method was considered for Boulder Dam, but was rejected because it would not create a temperature low enough to be effective under the prevailing climatic conditions.

The following letter from Mr. Walter shows the results that would have been obtained by precooling the concrete with crushed ice, and explains why the Bureau of Reclamation chose to counteract the heat of hydration by circulating first river water and then refrigerated water through the concrete after it had been poured:

EDITOR,
COMPRESSED AIR MAGAZINE

Sir:

In the March 1939 issue of the Compressed Air Magazine there appears an item on "Cracked Ice for Mixing Concrete" in which the cooling methods used at the Boulder Dam are compared with the proposed method to be used in Germany for cooling concrete by supplying the water to the mixers in the form of crushed ice.

It may be of interest that this method of temperature control was considered for use at Boulder Dam. The following analysis is taken from a report by Bureau engineers dated December 1, 1930:

Average temperature of concrete leaving mixer	40°F
Heat absorbed during transportation	5°F.
Temperature rise due to setting	40°F.
Final temperature obtained	85°F.
Mean annual air temperature	71.7°F.
Excess temperatures over mean annual	13.3°F.

These figures indicate that this method would have been inadequate to reduce the concrete temperatures to the mean annual level even though no allowance were made for the absorption of heat in the interval during which the surface of each lift is exposed between pours. In the warm climate prevailing at the Boulder dam site this absorption would have been large.

Later studies showed that an accumulation of water at the temperature of maximum density, or 40°F., was to be expected in the lower parts of the reservoir.

The final stable temperature of Boulder Dam, therefore, was estimated to be a gradient throughout the dam varying from the mean annual water temperature on the upstream face to the mean annual air temperature on the downstream face. It was considered necessary to cool the concrete in the various portions of Boulder Dam approximately to the values determined from this later estimate to put the dam in temperature equilibrium with its surroundings, which temperatures were from 13 degrees to 42 degrees lower than would have been possible with the method using crushed ice. Since the embedded pipe system was free from these limitations and offered better economy as well, it was adopted for this application.

Very truly yours,

R. F. WALTER
CHIEF ENGINEER
BUREAU OF RECLAMATION

Handy Magnifying Glass

DESIGNED primarily for tool and die-makers and machinists, the Magnilite, a combination magnifying glass and electric lamp, is well adapted for manifold inspection purposes in laboratories, factories, and shops. The instrument was developed by Mizzy, Inc., and is fastened by means of a universal joint to a stand from which it can be detached for use in any desired position. The lamp, which is said to be of a new kind, concentrates pure daylight rays upon the object which is to be examined, the lens provided for that purpose being an exceptionally large one, as the accompanying illustration shows. With the aid of the Magnilite, caliper readings are more easily determined, inspection efficiency is increased, and the eyestrain commonly associated with such close work is avoided.

Industrial Notes

Many bridges as now designed need all but one-sixth of their strength to support their own weight, says Prof. J. B. Wilbur, director of the new laboratory of structural analysis at the Massachusetts Institute of Technology. He predicts that aluminum will be the bridge-building material of the future.

Plastics lend themselves to widely diversified applications. Reports have it that an acetylene type of plastic is being made into a floor covering by the same equipment now used to manufacture linoleum. It is like the latter in appearance and has its sound- and heat-insulating properties.

While a pneumatic clamp holds a box or a package firmly in place on the table of a new machine, the latter automatically ties it with wire of 13 to 18 gauge, depending on requirements. In addition, it applies tension, twists the wire, cuts off the ends, and then gets ready for the next parcel. All this is done by depressing a foot pedal.

Narrow-blade band saws that are sold in coils and cut up in lengths as and when required are apt to cause the man in the stockroom trouble if they are not kept properly confined all the while. To prevent this, Continental Machines, Inc., has developed a neat package that it calls the Doall Precision Saw Carton. It apparently lives up to its name because if offers compact storage, solves the problem of handling and dispensing, and at the same time protects the delicate teeth against damage and the saw against rust. The company makes approximately 300 different types

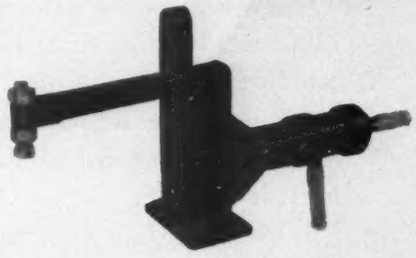
of Precision narrow-blade band saws and now packs in the new container all those that come in coils of 100 feet and more. As the accompanying illustration shows, the loose end of the coil projects from a slot at one corner of the box, which keeps the saw under control while as much of it as is needed is pulled out and cut off. Each carton is plainly marked and also provided with a cellophane-covered window so that the stockman can tell at a glance what type of saw is inside and how much of it is left. Doall storage cabinets are available.

Jenkins Bros., valve makers, who are this year observing their seventy-fifth year in business, recently concluded a novel contest for distributors' salesmen, the aim being to locate examples of their valves that are outstanding because of their service records. Length and severity of service and cost of maintenance were all considered, and in excess of 900 installations were reported. Collectively, they represent more than 300 centuries of service. One of the valves has been in use 60 years, during which period it has been opened and closed at least once a day. Seven winners have been announced, and they will be given trips by the company.

The first public demonstration of a new kind of motor fuel was made on June 9 by Dr. Francis W. Godwin of the research foundation of the Armour Institute of Technology. He drove a machine several blocks in downtown Chicago on "liquid coal," a black fluid composed of 60 per cent light fuel oil, 30 per cent pulverized coal, and about 10 per cent hydrocarbon, the small remaining percentage consisting of a secret substance. A 1939 model was used for the test run and was started with gasoline. As soon as the engine reached "driving heat" the supply was cut off and the liquid coal, carried in an auxiliary tank, was allowed to flow into the standard-type carburetor. A mileage of from 10 to 15 per gallon is expected; and it is believed that the fuel could be manufactured to sell at ten cents a gallon. According to Doctor Godwin, "We have about a year's research work to do on the liquid coal before it will be ready for the market."

Impervium is the name of a new protective coating that is said to have many of the desirable characteristics of rubber and, in addition, others which that material lacks. According to the producer, Paramount Rubber Service, Inc., it is a combination of synthetic resins that, with the exception of concentrated sulphuric acid at high temperatures and some metal salts, is proof against all acids, alkalies, and oils. Further claims made for it are that it has exceptional adhesive and dielectric properties; that it will withstand maximum temperatures of 160-180°F., depending upon service conditions; that it retains its elasticity over long periods; that it will char but not burn; and that, aside from a slight change in color, it is not impaired by exposure to sunlight. The product is suitable for the protection of metals and nonmetallic substances such as wood and concrete, and is especially recommended for insulating plating and chemical equipment. For test purposes the company is prepared to send free of charge a sample of coated metal, or to "imperviumize" at moderate cost at its own plant any small piece of laboratory or industrial equipment.

A new-model toggle clamp with built-in air cylinder has been put on the market by the Detroit Stamping Company. It is designed especially for multiple clamping, such as is required to hold large sheet-metal panels, and for clamping operations



in inaccessible places. The valve used is of the Ross type, and one suffices to actuate and to control a number of the clamps. These De-Sta-Co toggle clamps are said to work with a speed far in excess of that obtainable with hand-operated clamps such as are used for drilling, reaming, welding, or assembly operations.

The American Brass Company, Waterbury, Conn., has issued a new, illustrated catalogue covering its line of seamless, flexible metal tubing for handling steam, liquids, and gases wherever the service demands extreme tightness. It is particularly applicable where vibration or flexing occurs, and it is claimed that it has been flexed as many as 3,000,000 times without breaking. This tubing is used for conveying compressed air and other compressed gases on locomotives, in air-conditioning installations, and elsewhere. It is of corrugated-wall construction and is made in sizes of ⅛ inch up to 3 inches, inside diameter.

Sandbags, as most of us know, are frequently used in cases of emergency to keep water in bounds and to protect works of one kind or another in course of construction against the inroads of water. Effective though they are, they have one serious drawback. The containers are soon attacked by damp and mildew. To offset these destructive agencies, there has been developed what is called the Cuprammonium process for the treatment of jute bags which is said to give them a greatly increased service life. According to official tests, they lasted indefinitely, while the bags that were not proofed by the Willesden Paper & Canvas Works method began to deteriorate within from three to four weeks and were completely destroyed within five months.

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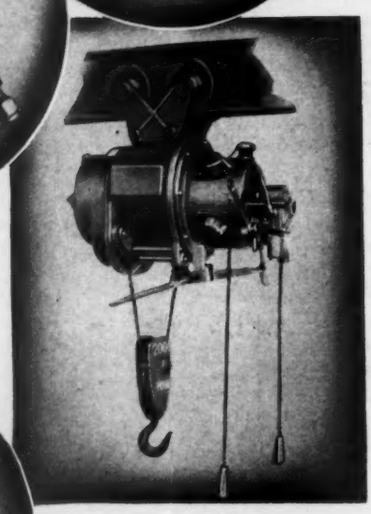
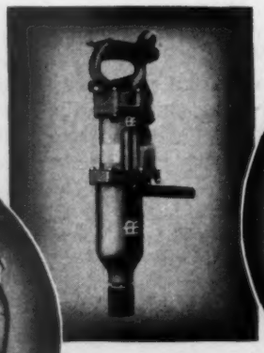
Size C2 Caliking Hammer

Size K1 Scaling Hammer

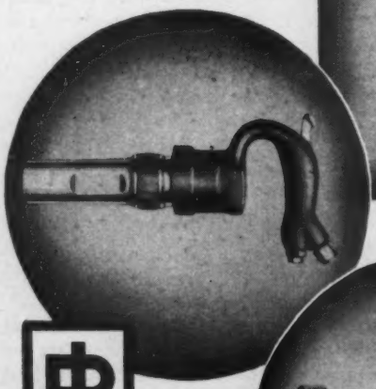


Size C Hoist

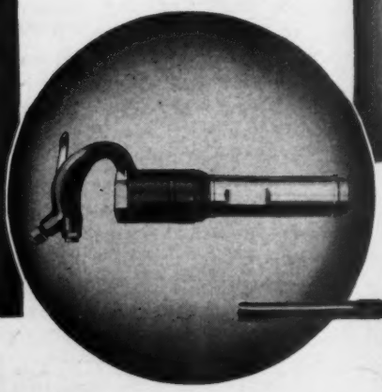
Size 533 Impact Wrench



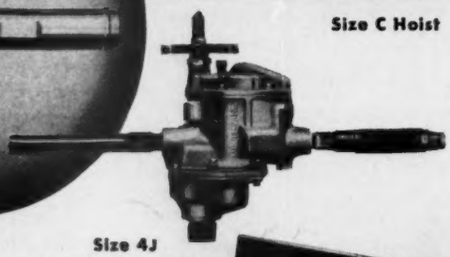
Size 200 Chipping Hammer



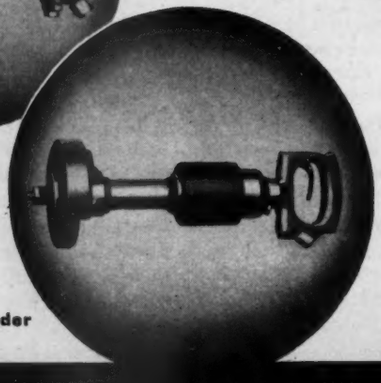
Size 6A Riveter



Size 4J "Multi-Vane" Drill



Size 3G Grinder



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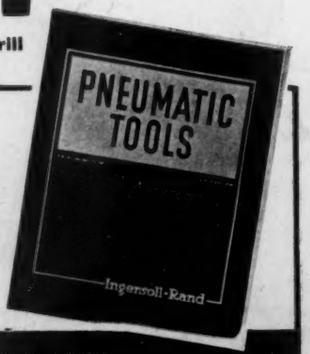

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